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TROPICAL AGRICULTURE

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The Principles of Farm Planning

A. Storrar

Assistant Director of Agriculture, Kenya

Considerable attention has been paid to agricultural research over the last decade, and rightly so, but it is not unusual to see the results of this invaluable work lost in the mire of a disorganized farming programme. Modern marketing methods and transport are gradually removing the barriers round the uneconomic farmer and if the farming enterprise in any one country or group of countries is to survive, then the agricultural produce must be competitive in world markets. It is necessary for a country to plan its agriculture on a national basis in order to achieve reasonable stability, and to implement an economic national policy the farming unit or units should be well organized and the various enterprises should be properly integrated so that maximum output can be achieved at the lowest possible cost.

National policy varies from country to country and so there is little need to discuss local details here, but the principles of farm planning which contribute to economic production and guard against the deterioration of the land through bad farming practices are fairly universal in their application.

The first problem in tropical and sub-tropical countries is the prevention of soil erosion, and conservation planning on a geographical basis is necessary no matter what the size of the farm unit. In the mixed farming areas of Kenya, the units vary from five acres in the heavily populated African Land Units to 5 000 acres in the European Areas, the average lying at about 15 acres in the former and 1 000 acres in the latter. Rainfall varies considerably and it can be as high as 100 in. or as low as 30 in., with widely different distribution patterns. Intensities are also variable but storms of up to 3 in. per hour should be expected and up to 5 in. per hour has been recorded in abnormal years. These intensity data emphasize the run-off problem and the erosion hazard if run-off is uncontrolled. *Figure 1* delineates a typical unplanned farm.

Adequate physical soil conservation work is required in areas of high rainfall intensities and this should be considered in two parts. First, district drainage or water control; and secondly, soil conservation on individual farms. The principal pre-requisite to district and farm planning is a suitable contour survey (*Figure 2*), as it is usually too difficult to carry out planning directly on the ground. Aerial, plane table, or grid surveys are all satisfactory and as a minimum, fairly accurate form lines run out by linear measurement and compass are required. As a general rule, slopes under 4 per cent require contours at 5 ft vertical interval, between 4 per cent and 8 per cent, 10 ft intervals, between 8 per cent and 30 per cent, 20 ft intervals, while over 30 per cent, 100 ft intervals suffice. *Figure 2* shows the first step taken by the farm planner, which is the classification of the land into the main slope groups discussed above.

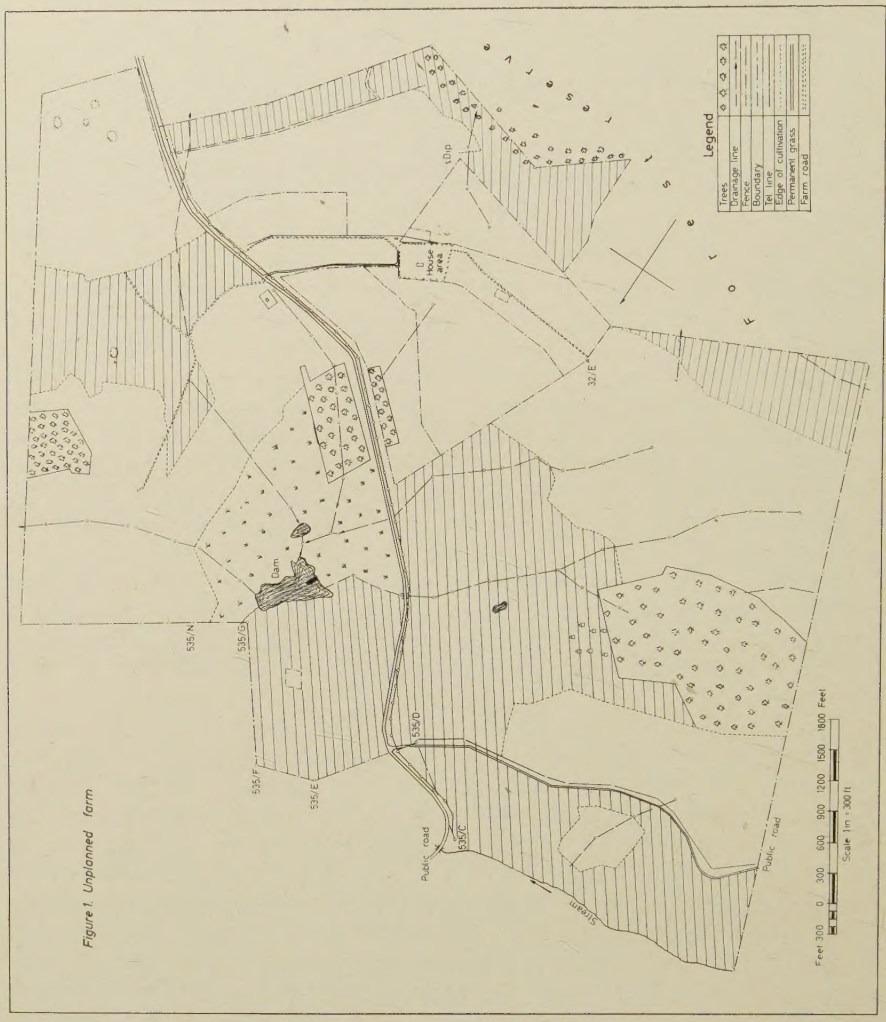

Figure 1. Unplanned farm

After survey, the next point to deal with is the natural drainage within a given watershed area. Drainageways must be marked out on the map and on the ground and inserted without reference to farm boundaries, local Council roads, etc. to begin with, as it is expensive and often dangerous to divert run-off water, particularly in large drainage areas. *Figure 3* shows a typical district drainage layout which is marked on the ground with iron standards which in turn are numbered as on the map, for easy reference. It is necessary to have grass in these drainageways to prevent gully erosion and to slow down run-off and it is advantageous to have rules to enforce the closure of such drainageways to cultivation. In addition, it is wise to establish the fact that the majority of the farmers are in favour of closure before it is effected, which then makes it possible for the community to bring pressure to bear on offenders.

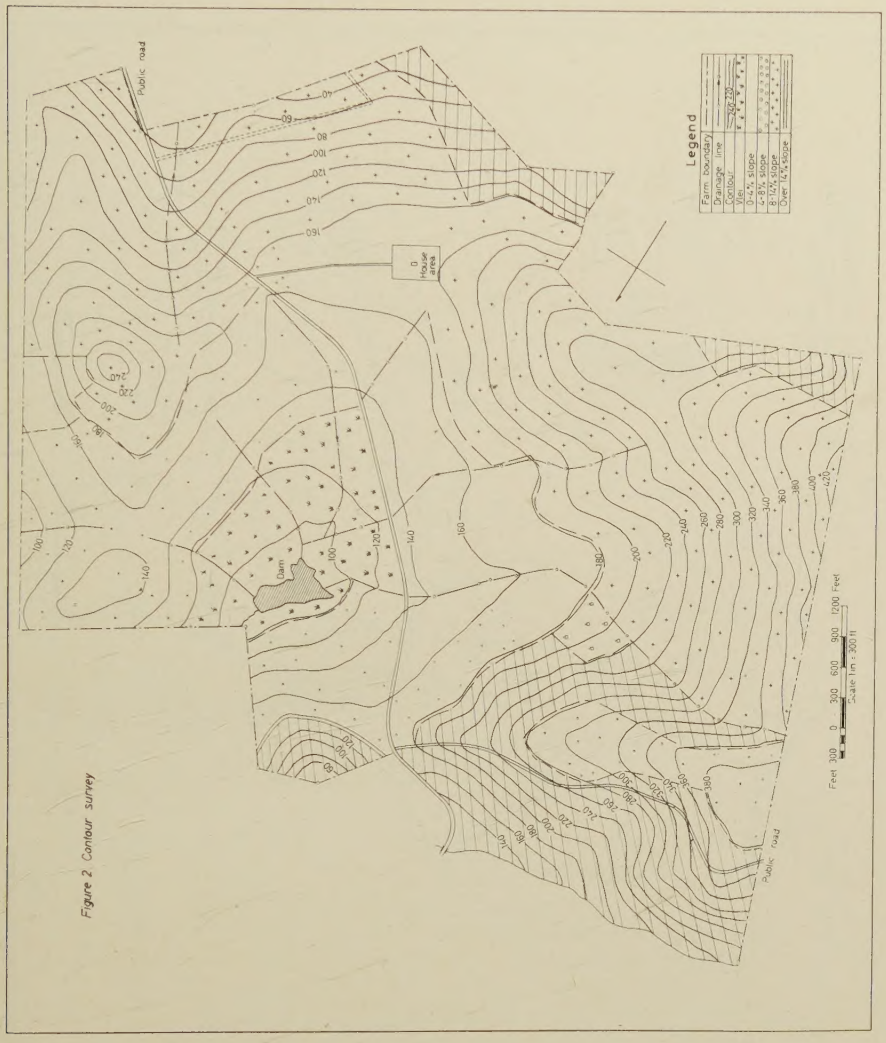

Figure 2 Contour survey

The maximum discharge of conservation works in any one direction should be 500 yards and therefore drainageways at a distance of not more than 1 000 yards are required. This allows discharge in two directions from a central point to a maximum of 500 yards each way, and careful scrutiny of district drainage maps allows the selection of the most suitable drainageways. This central point, or ' 0 ' point as it is normally termed, is the correct site for the alignment of farm roads where farms are large, or local access roads where they are small. Occasionally it may be necessary to construct artificial drainageways where the distance between natural depressions is more than 1 000 yards and these must be chosen very carefully to make the fullest use of the lie of the land. Artificial drainageways may also be necessary where it is not convenient to cross a public road, and 'A' in *Figure 4* is a good example of a diversion down the side of a road to join

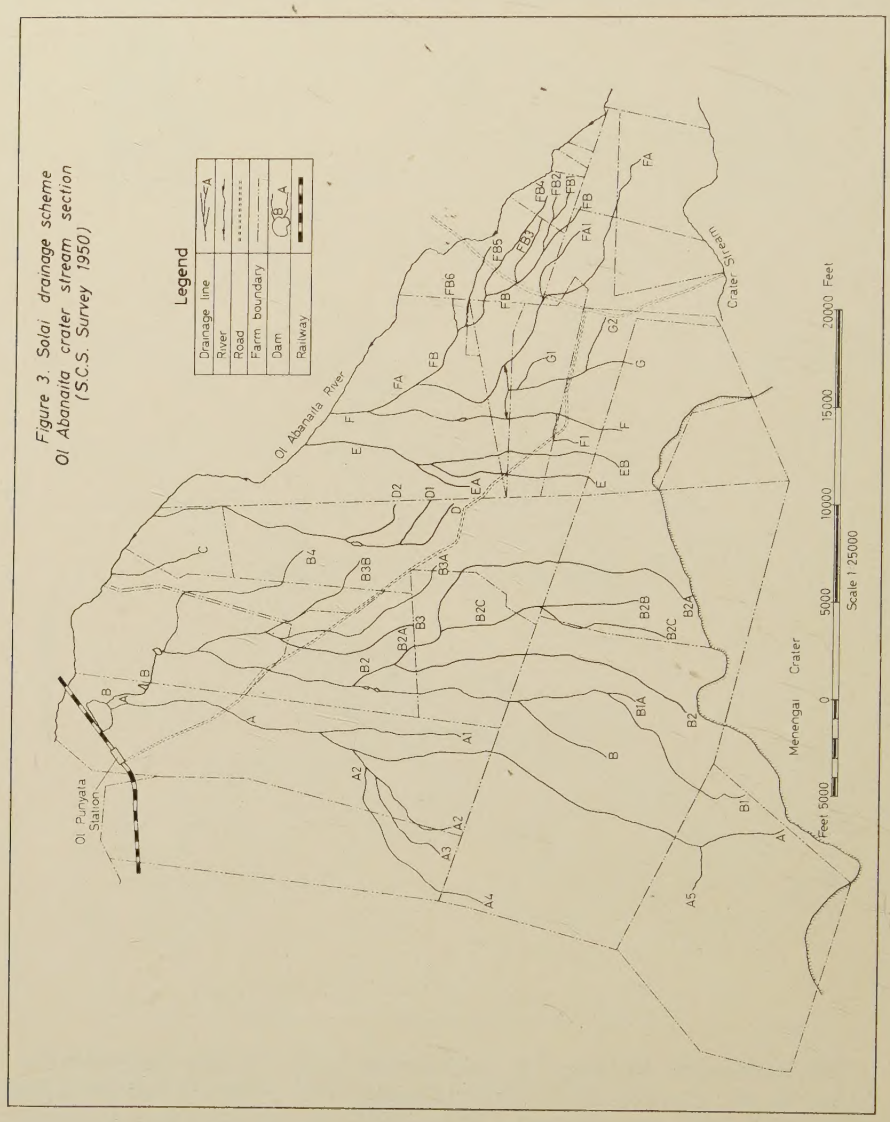

Figure 3. Solai drainage scheme Ol Abanaita crater stream section (S.C.S. Survey 1950)

up with ' B ' in a matter of 400 yards. Equally, to achieve a good field layout on the farm, it can be advantageous to divert over a short distance as with drainageway A. The natural course is diagonally across the Field Vlei No. 29, but as this interferes with a reasonable field layout it is diverted as shown. The width of drainageways will depend on the area of the cross section together with the size of the catchment area, and engineering advice should always be sought to determine this. Retaining banks may be required on the edge of drainageways with a flat cross section and once again an engineer should be consulted.

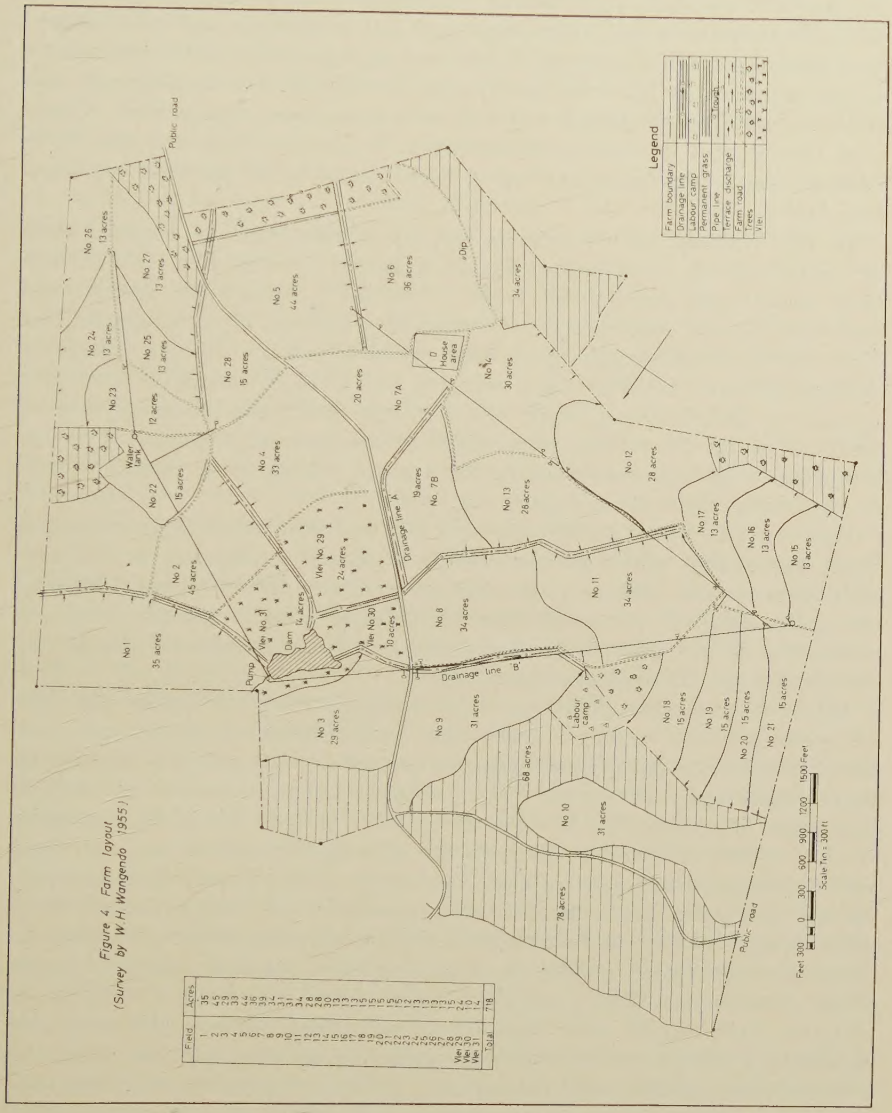

Figure 4 Farm layout
(Survey by W H Wangendo 1955)

When district drainage has been completed, the basis for farm planning has been laid, and in this article will be discussed the principles as they apply to the larger farms in the European areas of Kenya.

Practical experience has shown that land under a 4 per cent slope, between 4 per cent and 8 per cent, between 8 per cent and 14 per cent and over 14 per cent, requires different methods of protection and therefore the first step is to consider the varying slopes which eventually affect conservation methods. For example, in *Figure 4* Field 8 has a slope under 4 per cent and conservation measures are represented by a diversion ditch

on the field boundary and contour cultivation within. Field 4 has a slope between 4 per cent and 8 per cent and this requires broad base terraces for protection. On the steeper fields between 8 per cent and 14 per cent—which are most suitable for pyrethrum and fodder farming—broad base terraces would not be satisfactory and the narrow base type is used. Land over 14 per cent is considered unsuitable for arable crops and should be used for permanent grassland up to approximately 30 per cent and over this, forest.

In this country, where normal run-off is calculated at about 1 cusec per acre, cut-off drain capacities are designed to deal with the acreage they protect and the normal grade is 1 in 200. Broad base and narrow base terraces are constructed to a capacity of about 10 to 12 square feet either on a variable grade or an even grade of 1:200. In calculating the vertical interval between these terraces the formula normally used is a quarter of the percentage slope plus 2 ft, but where the husbandry is good and where the soil is absorbent, this vertical interval is increased to one and a half times or even to double the normal. Judgement should be used in this matter as well as engineering tables.

Any definite change in soil type must also be indicated on the preliminary map, particularly where porous and vlei soils are contiguous, as different soils often require different conservation measures and cropping. *Figure 2* shows an area of vlei which has been demarcated separately from the remainder of the farm which has a porous volcanic soil, and the former will require special drainage treatment.

When these various details have been demarcated, the farmer can then be presented with a map showing the total amount of arable and non-arable land on his farm, whereupon the overall farming policy to be adopted can be discussed. A suitable type of rotation can then be evolved and it is important to consider the fact that the number of fields should be a multiple of the number of years in the rotation so that the annual crop acreages can be standardized and suitable machinery units chosen. For instance, on this farm the flatter lands and larger fields are being worked on a seven course rotation and therefore there are fourteen fields. The steeper lands are also being worked on a seven course rotation and once again there are fourteen fields, but if an eight course rotation had been more suitable there would have been eight or sixteen fields. The field size should be a compromise between suitability for grazing and that which the configuration of the land will allow. Wherever possible, the tendency should be towards long narrow fields to allow ease of cultivation but at the same time care should be taken not to increase unduly the cost of fencing. In this country, fields of between 20 and 50 acres are considered to be particularly suitable, but where pyrethrum growing takes place, the field size often drops to 10 or 15 acres. Where permanent crops, such as coffee and tea, are to be incorporated within a general mixed farm, the most suitable land for the crop must be chosen and excised before rotational planning commences. Wherever possible the boundary of the plantation crops should follow a contour or natural boundaries.

After the fields have been established, roads and pipelines should be indicated, and wherever possible water should be carried to every field

but the main lines should come first. The availability of water should be considered when working out a re-seeding policy within the arable fields so that the fields lying near to the main line can be dealt with first, as this will help to reduce initial costs. Reduction of initial capital costs always releases money for annual profit-earning purposes and it is therefore important to keep these costs to a minimum.

Farm buildings should be sited at a central point unless it proves virtually impracticable to move any existing buildings. The buildings on this farm were retained on the original site as they are reasonably central to the main arable area. Where permanent silos are envisaged it is important that they should be located at suitable points throughout the farm to save cartage and facilitate feeding. Where the more modern methods of making silage in clamps can be included, they should be used in preference to permanent sites as they reduce cartage to the bare minimum, reduce initial capital outlay, and allow self feeding when the silage is required.

When these matters have been decided, then comes the problem of the manipulation of crops and grass within the fields. A general policy of re-seeding the oldest crop land and breaking up the oldest grassland is sound but not always practical. It is considered necessary to avoid a situation whereby all the crops will be at one end of the farm and the grassland at the other and therefore when working out individual field rotations this must be kept in mind. The amount of breaking and re-seeding must also be kept within the bounds of practice and it is imperative to relate the grassland to the stock available at all times, otherwise valuable land is wasted. Also the suitability of certain crops to certain fields must be studied and it often happens in this country that where land has become unsuitable for the growing of wheat or maize, due to over-cropping, good crops of oats can still be grown. At this stage portions of old arable fields which have become part of grass fields in the new layout should be seeded right away under the next crop and conversely old grassland broken into a new arable field. In the early stages where limited funds are available for fencing and piping, it may be necessary to run fields of grass together to economize on expenditure but at no time should one lose sight of the eventual distribution of crops throughout the farm. Great care should be taken to see that the previous economy of the farm is gradually fused with the new, in a practical manner, otherwise financial hardship may well be experienced.

When working out the rotation, careful attention should be paid to machinery requirements so that the farm is not over-capitalized with a wide variety of implements. For instance, maize and wheat have different requirements and although it may be considered agronomically sound to alternate these two crops in the rotation, the principle would have to give way if the acreage of either were insufficient to utilize expensive tackle fully. It will be seen therefore that there are many considerations which influence the change-over to a new rotation, and when drawing up the final plans due attention must be paid to each point so that each move is practical and economic.

The next step is the stocking of the farm, and in Kenya it is normal to find a farmer with a modest herd of cattle for the acreage which he holds. For financial and veterinary reasons it is often found necessary to enlarge

the herd on a natural increase policy and the anticipated rate of increase of female stock is 40 per cent of the number of cows less any culling which may be required. When full stock numbers have been achieved it is then only necessary to cull for productivity and eventually only 20 per cent female replacements need be retained annually. The number of cattle on the farm has to be related to the grassland available, but obviously the re-seeding policy can also affect the carrying capacity of the farm. Therefore, the anticipated carrying capacity of the leys must be carefully allied to the number of stock held. The number of cattle also has to be associated with the production of fodder for the dry season; the average cow producing in the region of two gallons of milk daily will require in the dry weather, in addition to rough grazing, 40 lb of silage for 180 days and 10 lb of hay for 120 days, or roughly 3·5 tons of silage and 0·5 ton of hay per annum. This can be allowed for out of the grassland, from a silage and hay crop such as oats, or from both. One should aim at the production of fodder with a nutrient ratio of about 8 to 1 on Henry and Morrison standards for a two-gallon cow, but this will require variation according to the milking capacity of the herd. Where milk is particularly valuable, it may be wise to grow concentrates on the farm for the higher producing cows, but before this is done the cost should be carefully compared with that of proprietary foodstuffs suitable for the purpose. One should also carefully investigate the alternative merits of all-the-year-round calving and seasonal calving. Obviously, where fresh milk is the aim, the former method would have to be used and provision of silage and hay along the lines suggested would be necessary. On the other hand, if butterfat is the aim, it may well pay to calve all the cows seasonally so that the milk is produced from the grass, and then a reduced quality of fodder would suffice for the period when the cows are dry. In a country such as Kenya, it may prove to be possible, particularly in the maize areas, to draw all the milk from the grass and bring the cows through the dry weather on crop residues alone, and this will lead to quite a reduction in the cost of production. Once again, each point must be very carefully considered.

On a dairy farm, where there is no fresh milk trade, the skim milk appears as a by-product and consideration should be given to its utilization through pigs. A 500-gallon cow should provide sufficient skim milk, after allowing for the removal of cream and the feeding of a calf, for two bacon pigs per annum, which allows 150 gallons of skim milk per pig. Each fat pig requires 700 lb of grain in addition to the skim (this includes an allowance for the sow) and provision should be made within the rotation for the production of this grain, unless it can be purchased more cheaply elsewhere. Similar calculations are necessary if the farmer wishes to embark on a poultry economy, but whatever the requirements every attempt should be made to make full use of the by-products on the farm, which eventually leads to greater profits.

The eventual aim of the farm which is being planned is most important, but even more important are the practical means of arriving at the ideal. Each step for each year should be carefully considered, remembering in particular that grassland re-seeding and fodder production have to be one year ahead of stocking.

Capital expenditure has to be carefully allocated so that one section of the farm does not suffer at the hands of the other and that there is no wastage. The total amount of piping, fencing, conservation work and building is known and, having worked out the rotation with a view to saving wherever possible, only the minimum development required each year should be undertaken. Conservation works should take priority over all others, but here also economy should be kept in view and fields going back to grass immediately, together with those under grass, should not be treated mechanically for conservation until such time as they are broken up again. Piping should only be taken to the main parts of the farm and fencing erected as each field goes back to grass. Wherever possible the farmer should start with movable pig houses and milking bails and if necessary such things as temporary troughs, so that maximum savings can be made with a view to directing any capital available towards revenue-earning purposes such as the purchase of cows, pigs, sheep, etc. One must also be careful in the use of profits for further development and on an average mixed farm it is suggested that one third of the profits should be used for capital development, one third set aside against depreciation of machinery and the remainder held as a money reserve. Such a procedure is recommended so that if an unheralded slump occurs the farmer will have liquid cash to carry on with his enterprise.

Farming is both an art and a science, but it is also a business and if it is to be a success then it must be as carefully planned and calculated as any other commercial organization. Good planning and good farming make good business and there are many enterprises today in Kenya being developed along the lines suggested with considerable success.

(*Received December 1958*)

The Maintenance of Soil Fertility in the Southern Guinea Zone of Northern Nigeria (Tiv Country)

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The Southern Guinea zone stretches from east to west across the centre of Nigeria. It is intermediate climatically between the tropical rain forest and the Northern Guinea zone with its long dry season (Keay, 1952). The vegetation consists of isolated, fairly tall trees surrounded by a large number of small stunted shrubs with tall grasses, the chief genera being *Andropogon*, *Pennisetum* and *Hyparrhenia*. Rain forest outliers along the stream banks, taller growing perennial grasses and a much more abundant mixture of small tree species distinguish the area from the Northern Guinea Savannah. It differs from the rain forest of the south in that there is no abundance of creepers, the trees are usually smaller and the area is swept by bush fires in the dry season. The annual rainfall is approximately from 45 in. to just over 65 in. which nearly all occurs between the end of March and the beginning of November.

The maintenance of soil fertility in this area is comparatively easy where the population is not large and a reasonable fallow period is possible. Where the population increases beyond a certain point there is a subsequent decrease in the length of the fallows to a dangerously short period due to more and more land being brought into cultivation each year. Experiments and trials have been carried out at Yandev Agricultural Station to try to discover an answer to the fertility problem and a considerable amount of information has been acquired over the last 30 years.

There are a few areas where the soil is rich and in these places the fallow period can be reduced to one year or even less. These areas are either along the river banks, around springs or in slight depressions where there has been deposition of chemical nutrients and clay particles over many years. Outside these fertile areas the soil either requires a rest period or the addition of some fertilizing material, either of local origin or brought in from outside. The maintenance of soil fertility, let alone the improvement, has become of vital importance where the fallow period is becoming excessively short.

Owing to the discovery that leguminous and green manure crops were beneficial in the temperate regions it was considered that they would probably have similar effects on the soil in the tropics (Faulkner, 1934). In this country this idea has proved to be over-optimistic, both in the more southern regions (Vine, 1954) and perhaps even more so in the Southern Guinea zone.

First, the effect of green manures is of short duration. There is some benefit from different green crops but it is only shown up by plants grown directly afterwards and ' follow-on ' crops seem to show little or no response.

The high annual temperatures and seasonal moisture content cause rapid decomposition of residual organic matter (DIAMOND, 1937). This effect, combined with the heavy concentration of rain which encourages rapid percolation of plant nutrients and considerable mechanical breakdown of soil structure, soon destroys any beneficial effects of short-term treatments. Thus the effect of green manures is very temporary.

Secondly, there is an indication that leguminous crops are not as beneficial as had been hoped. This was an unexpected result and certainly seems to suggest that either leguminous crops do not have such power to fix nitrogen as they do in the temperate regions or that this nitrogen is very quickly lost.

Another difficulty is that although a number of green manure crops have been tried they all have some disadvantages. Cowpea (*Vigna unguiculata*) is difficult to grow quickly, the roots of Sunnhemp (*Crotalaria juncea*) are tough, fibrous and difficult to dig in, and pigeon pea (*Cajanus cajan*) does not grow enough green material in a short time. *Mucuna* (*Stizolobium* spp.) was found to be by far the most promising but even this green crop was not always easy to establish in certain years in this area.

It was also noted that the treatment of the green crop had no effect on the result. It was found that there was virtually no difference between burning or digging in the crop while still green. Also, unlike temperate regions, the stage of growth at which the plant is dug in to the soil does not seem to be very important provided sufficient green bulk has been attained. In other words the plants can be allowed to mature and the seed can be harvested with no effect on the following crop.

Reviewing the work done at Yandev Agricultural Station it is apparent that short-fallow green manure crops might have been reasonably successful if an ideal green manure plant could have been found although even then the maximum yields could only have been obtained by bringing in plant nutrients from outside (RICHARDSON, 1946). An ideal crop would be one that could be established easily with little soil preparation, was sufficiently quick growing to provide a great abundance of green material in the early rains, vigorous enough to compete with the weeds, able to grow well on a porous soil of medium to poor fertility and could be easily dug into the ground. From the extension point of view it is almost essential for some part of the plant to be edible as an incentive for the local farmers to grow it and it would also be an advantage if it could be burnt off to avoid the farmer having to indulge in the laborious practice of digging in the green material. Unfortunately no such green manure crop was available and it was therefore decided to investigate the system of extended fallows.

It was noticed that Spear grass (*Imperata* spp.) came in very soon after the land was put down to fallow, especially on run-down areas, and it seemed to have no regenerative effect on the soil. Only after one or more years do better species become a major part of the sward. It was thought that by establishing artificially at the outset certain large grasses, especially Gamba (*Andropogon* spp.), the effective fallow period could be shorter and would give better results. It was also decided to investigate a long-growing legume, and pigeon pea was the obvious choice.

Pigeon pea, as a long-term legume, has the advantages of being tolerant of a wide range of soil types, growing quickly, giving a good soil cover,

producing edible seeds and requiring little or no attention once it is established. It is an advantage to cut it back in the second year which causes the stump to ratoon and produce a bushy plant rather than a tree. On the other hand it has some disadvantages. It does not always establish as well as might be desired, it is not relished as a food by many African farmers in the area and it starts dying out in the second year of the fallow which allows more and more weeds to come in. Nevertheless pigeon pea can be considered a long-growing legume plant that is fairly near the ideal for the zone and one which would indicate the results that could be expected from a legume fallow.

It has been shown that a three-year fallow is adequate to maintain and in some cases improve, the soil fertility when it is followed by a three-year cropping cycle. Thus it may be said that every year of cropping requires a year of fallow on an average soil of medium to poor fertility. Fallows of less than three years do not seem to be sufficient. On the other hand there is little doubt that a three-year cropping cycle can be continued with only a one- or two-year fallow for a considerable time without the area becoming so infertile that planting crops is not worth while. However, once a soil has become infertile a much longer fallow period is required to rejuvenate it.

Thus there will be a fall in the fertility of the soil where over-population results in only a two-year fallow being possible but it will probably occur so slowly that the local farmers will not worry unduly for some time. The fact that the difference between the after-effects of two- and three-year fallows is not startling is the main reason why it is difficult to impress upon the local people the danger of continually reducing the length of fallow.

Table 1. Results of three separate trials where three years of crops have followed a three-year fallow. Results are in lb/acre

Trial 1

Fallows	*1st year Yam*	*2nd year Millet and sorghum Total grain*	*3rd year Benniseed*
Pigeon pea fallow	8154	833	211
Gamba fallow	8435	846	238
Natural regeneration	7830	791	210

Trial 2

Fallows	*1st year Yam*	*2nd year Cowpea*	*Millet and sorghum Total grain*	*3rd year Benniseed*
Pigeon pea	8447	124	787	459
Gamba	7610	120	773	411
Natural regeneration ...	6915	104	811	404

Trial 3

Fallows	*1st year Yam*	*2nd year Millet and sorghum*	*3rd year Benniseed*	*Three-year fallow*	*7th year Yam*	*8th year Millet and sorghum*	*9th year Benniseed*
Pigeon pea	2743	1280	270		12659	691	350
Gamba ...	2559	1149	237		11715	798	357
Natural regeneration	2709	1370	238		11507	851	343

A comparison of yields after Gamba, pigeon pea and natural regeneration fallows on a number of long term trials (*Table 1*) indicates that there is no clear difference between them although the yams and benniseed after the two former treatments gave slightly higher yields in nearly all cases. It seemed as though there was a greater overall improvement after pigeon pea over the years which would agree with findings in Ghana (Nye, 1957) but in this area this largely appears to depend upon whether it is possible to get the pigeon pea well established during the fallow period. On the average the labour involved in planting fallows can only be considered worth while if some product from the fallow crop is of direct use, either in the form of grass for the cattle or pigeon pea for human consumption.

Another experiment was carried out at Yandev to discover if the establishment of wild woody species would improve the effect of the fallow, using *Lophira alata* and *Afzelia africana*. The shrubs were established at 6 ft and 12 ft apart in a nine-year fallow and left in during the following crop and fallow cycles. These treatments were compared with a straight Gamba fallow and there is no doubt from the results that planting permanent woody shrubs will give a lower yield, especially with close spacing. The use of larger trees at wider spacings might possibly be more worth while, especially when the firewood from them is taken into account.

Although it has been found in this zone that planted fallows are worth while the local farmers, even in the over-populated areas, have not accepted the idea. There are two main reasons. First, the system of land tenure in the area does not encourage the farmer to look after his land. The Tiv farmer only has the right to farm a certain area and he can be removed by the native authority at any time with compensation for his house and standing crops only.

Secondly, the peasant farmer is loath to grow a fallow crop that does not yield anything that is of direct use to him. The Idoma, a small tribe on the boundary of the Tiv, eat pigeon pea as part of their diet and it is sometimes grown as the last crop in the rotation in which case it persists throughout the first part of the fallow. This seems to suggest the best propaganda approach for encouraging suitable fallow crops, but up to the present little progress has been made in Tiv country.

Having done a considerable amount of work on green crops and fallows, it was then decided to investigate the possibility of raising the fertility by the use of cattle pen manure Numerous experiments have been carried out on this subject and considerably increased yields of most crops were obtained. Yams, millet (*Pennisetum* spp.), guineacorn (*Sorghum vulgare*), maize, sweet potatoes and ginger all respond well to manure and only in the case of benniseed (*Sesamum indicum*). was the response not worth the trouble of application.

The usual Tiv rotation is yams in the first year, grain crops in the second year and benniseed in the last year. It was found that it was best to apply the manure to the millet and guineacorn year rather than to either the yams or benniseed. Another interesting discovery was that there was little difference between the effects of manure straight from the pens and manure that had been composted.

The very beneficial effects from applying manure encouraged further work on the subject to see if by using it continuous cropping was possible. It was found that two tons per acre of manure applied to either the yams or the grain crops would maintain the fertility on continuous cropping while three tons per acre would gradually increase crop yields and one ton per acre would result in a steady decline. It had already been noticed that there was a definite residual value from manure that lasted for at least two years.

This knowledge was a considerable step forward but once again the difficulty was to get the local farmer to follow this advice. Unfortunately manure is not easy to produce in sufficient quantities due to the effect of trypanosomiasis reducing the cattle population (King, 1939) and the local haphazard methods of keeping livestock. Even when manure can be found it is heavy to carry to the fields and it is largely used on garden crops around the compound.

It was therefore decided to concentrate work on artificial fertilizers. It was soon found that the usual three-course rotation could be extended a year by applying 150 lb of superphosphate and 150 lb of sulphate of ammonia per acre to either a second year of yams or of grain crops. Work is being carried out to see whether continuous cropping would be possible with artificial fertilizers and there is every indication that this is possible provided adequate quantities are applied. *Table 2* gives results from fertilizer trials. Nitrogen, as further south (Irving, 1956), and phosphate, as further north (Greenwood, 1951), gave increases with some crops but lime and potash

Table 2. Results of a DNPK trial with continuous cropping, 1950–1958

Rate per acre	'50 *yam*	'51 *G.C.*	'52 *B.S.*	'53 *yam*	'54 *G.C.*	'55 *B.S.*	'56 *yam*	'57 *G.C.*	'58 *B.S.*
FYM									
Nil	126	545	422	108	509	287	79	379	97
1 ton	131	605	432	112*	840*	331*	87*	599*	125*
2 tons	132	668*	433	119*	992*	317*	94*	824*	120*
S/A									
Nil	123	576	418	105	746	269	81	516	101
50 lb	131*	631	433	117*	787	317*	88*	639	115
100 lb	135*	610	435	117*	808	350*	91*	646	127
Super									
Nil	126	555	398	109	649	296	84	507	109
50 lb	128	653	471*	120	845*	324*	90	577	118
100 lb	134*	609*	418	111	847*	315	86	717*	117
Potash									
Nil	127	613	415	119	740	311	87	550	116
50 lb	133	636	448	114	814	316	90	632	113
100 lb	129	568	424	106*	788	308	83	620	113
S.E.	2	24	15	2	36	9	2	44	7
5% Sig. D.	7	68	42	7	103	24	7	126	19
1% Sig. D.	9	91	57	9	137	33	9	169	—

G.C. = Guineacorn. B.S. = Benniseed

Yields are all in lb/acre except for yams which are in cwt/acre.

Guineacorn was interplanted with millet, and yam with cowpea, but only the results for guineacorn and yam are shown as these are the main crops.

The asterisks show where the treatments have given a 5 per cent significant difference over nil and sometimes between one and another. It should be noted that yam yield was significantly depressed by muriate of potash in 1953.

had no beneficial effect either singly or in combination with other fertilizers, in fact the latter was sometimes detrimental. Sulphate of ammonia can now be recommended in the area for use on rice, yams and cassava. Once again there were considerable difficulties in getting the local farmers to use this method of increasing crop yields although more interest has been shown recently. In this case it was a question of finance. A bag of 40 lb of sulphate of ammonia costs 15*s* in the area at the present time which is a considerable outlay at the planting period when the farmers are usually short of capital.

SUMMARY

The problem of maintaining soil fertility in this area has received considerable attention. Of the four approaches to the problem only short-term green manure crops were to all intents and purposes a failure. Fallows, cattle pen manure and artificial fertilizers all gave worthwhile results and a combination of all three would probably be the answer to most or all of the fertility problems of the area. The main difficulty always is to get the peasant farmer to put into practice the knowledge that has been gained.

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Increased Cocoa Production by Foliar Copper Applications as an Effect Additional to Witches' Broom Disease Control

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EFFECT OF COPPER–SANDOZ ON CONTROL OF WITCHES' BROOM

In Trinidad, Thorold (1953) and Holliday (1954) achieved some control of Witches' Broom disease when they found that high-volume spraying of cocoa with copper fungicides led to reductions in the amount of vegetative brooms produced and in pod losses; dithane, a zinc fungicide, proved ineffective. The diminution in pod infection brought about by copper spraying varied between 30 and 70 per cent.

Mist-blowing trials with Kiekens knapsack machines against Witches' Broom have been carried out in Ecuador for a few years; the results show that this system of control is efficient and can be recommended for use on a commercial scale in heavily infected areas where productivity is high.

In Ecuador, Witches' Broom disease is, as a rule, a very serious matter. Heavy losses of crop are occasioned by attacks of the disease. Cutting away diseased tissues offers no final solution, partly because of the considerable stature of the trees and partly because of the enormous number of brooms developed. The wet season, in Ecuador, lasts from January to June; the rest of the year is completely dry. Sporophores begin to appear usually at the end of February or the beginning of March, and in April and May Witches' Broom infected pods can be seen amongst the crop. During the next three months the proportion of pods attacked rises rapidly; often 80 per cent of the crop becomes diseased even in areas where the cutting of brooms is practised. After September the loss of pods from Witches' Broom disease rapidly becomes less severe and may fall to nothing as a result of the onset of the dry period in July (or the second half of June). There are two crops in Ecuador —one at the end of the year, usually little affected by Witches' Broom, and another in the wet season, often more or less completely lost by disease attack.

Mist-blowing trials with dithane were started at hacienda Clementina in 1955. They continued for one year, using about 200 litres of liquid per hectare (equivalent to 17·6 imperial gallons per acre) at a 2 per cent concentration of the fungicide. Some areas were sprayed once monthly, others twice monthly. In neither case was any control of Witches' Broom achieved, either of broom formation or of pod infection.

In July 1956, trials were started with Copper–Sandoz in the same experimental areas, again using approximately 200 l./hectare of a 2 per cent suspension. The mist-blowing operations were mainly directed towards coverage of the pods, but part of the mist also entered the canopy. The

experimental area carried cuttings of ICS 1, five to six years old, well developed and bearing satisfactorily. There were two trial series, one with monthly intervals and one with half-monthly intervals; each series consisted of sixteen blocks, containing approximately 40 plants each (all blocks were of the same dimensions but some had occasional plants missing, eight of them being treated and the other eight left as controls).

As the trials were begun at the beginning of July it was necessary to wait several months to see what effects the spray treatment exerted. Data are given, therefore, covering the period October 1956 to December 1957, when the trial terminated (*Table 1*). The experimental period is subdivided into three smaller intervals, each of which represents a natural cropping period influenced by the wet and dry season.

Table 1. Numbers of pods reaped from untreated plots and from plots mist-blown twice a month with Copper-Sandoz

Period	Healthy pods		W.B. pods		W.B. pods per 1000 healthy pods	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Oct. '56 to Apr. '57	8710	10185	187	18	21	2
May '57 to Sept. '57	789	2529	1548	645	1951	255
Oct. '57 to Dec. '57	3140	4274	116	27	37	6

The results show clearly that the crop which develops in the dry season is hardly affected by Witches' Broom disease; and that without treatment the wet season crop is largely lost. Mist-blowing with Copper–Sandoz was very effective; the incidence of Witches' Broom pods on sprayed trees was only 13 per cent of that on unsprayed trees.

Table 2 gives a breakdown into monthly counts for the period May 1957 to October 1957. In the first months of the season of Witches' Broom attack, the number of pods reaped on the untreated plots considerably exceeded the number of pods from the treated plots, particularly so in the

Table 2. Monthly pod harvests from plots mist-blown twice a month with Copper–Sandoz

Month	Healthy pods		W.B. pods	
	Untreated	Treated	Untreated	Treated
May 1957	19	20	22	3
June 1957	111	9	621	270
July 1957	57	66	401	181
Aug. 1957	109	650	137	35
Sept. 1957	493	1784	367	156
Oct. 1957	938	1973	31	5

case of diseased pods. In later months, however, the treated plots gave greater pod harvests than the untreated. The apparently heavier cropping in untreated plots in the first few months is due to premature ripening of pods attacked by *Marasmius perniciosus*. For purposes of estimating the effect of spraying, it is therefore better to confine attention to periods of several months rather than to single months.

The results obtained from the application of monthly sprays are given in *Table 3*. On the whole, the result was the same as with spraying twice a month, but the control, as might be expected, was less effective.

Table 3. Numbers of pods reaped from untreated plots and from plots mist-blown once a month with Copper–Sandoz

Period	Healthy pods		W.B. pods		W.B. pods per 1000 healthy pods	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
Oct. '56 to Apr. '57	6038	6082	20	18	3	3
May '57 to Sept. '57	684	1475	424	214	620	145
Oct. '57 to Dec. '57	2099	1945	18	9	9	5

The numbers of vegetative brooms cut in the treated and untreated areas on two occasions are given in *Table 4*. The benefit derived from mist-spraying with Copper–Sandoz is at once apparent.

Table 4. Numbers of brooms cut in untreated plots and in plots mist-blown with Copper–Sandoz

Month	15 days' spray interval		30 days' spray interval	
	Untreated	Treated	Untreated	Treated
July 1957	1383	878	4420	3378
Dec. 1957	1645	684	1668	530

Broom formation was considerably reduced in the sprayed areas, despite the fact that these areas represented small, isolated pockets in an area heavily infected with Witches' Broom disease. Because brooms often develop from infections derived from distant foci, it could be argued that the effectiveness of the spray treatment would be much enhanced when large expanses of infected cocoa were treated at the same time. This was, in fact, clearly demonstrated by extensive trials carried out on hacienda Esperanza (*Haciendas de Carmignani*) at Vinces in Ecuador from 1957 to 1958. These experimental areas carried stands of old 40 ft high trees which for the last 30 years have always been heavily infected with Witches' Broom disease. No cutting-out of brooms has ever been practised. In these desolated areas mist-blowing trials were begun in November 1957, using a high-reaching Kiekens mist-blower to treat the canopy. Monthly spraying was adopted, the volume of 2·5 per cent Copper–Sandoz suspension applied at each visit being some 150 litres/hectare (13 imp. gallons/acre). As it was clear from the results obtained from hacienda Clementina that Witches' Broom infection was of little importance in the dry season, the spray treatment at hacienda Esperanza was carried out in the wet season only, starting one month in advance of the rains which, in this area, usually begin in December. One section received four monthly sprays (stopping after the February application) and another received eight consecutive sprayings.

When I visited these areas in June 1958, the result was strikingly apparent. The leaf canopy, especially in the area sprayed eight times, had recovered remarkably from the long-standing infection by Witches' Broom disease. The canopy looked healthy, dark green, without dead leaves and with very few new brooms. Pod infection was reduced to a very low level. *Table 5* gives the yields from equal areas left untreated, sprayed four times and sprayed eight times, in the period 1 January to 15 May 1958.

Table 5. Yield of dry cocoa in quintals from untreated and mist-blown areas, each approximately 200 acres in extent (52 500 trees)

Untreated	*Mist-blown four times*	*Mist blown eight times*
232	368	420

The increase in yield following the spray treatment was considerable and the effect of only four applications at the beginning of the wet season was especially remarkable. *Monilia* disease, it should be mentioned, was also present in the area, but this took second place to Witches' Broom disease. The trials described indicate that mist-blowing with Copper–Sandoz can be developed into a commercial practice in areas capable of giving good yields but which suffer seriously from Witches' Broom attack. The spraying might even make the cutting-out of brooms superfluous.

EFFECTS OF COPPER ON FOLIAGE OF CACAO PLANT

During the time that the above-mentioned trials as well as trials to control *Phytophthora* were carried out in several countries, it became obvious that small amounts of copper applied to the leaves exerted a beneficial effect on the leaf canopy of the cacao plant.

After a year of mist-blowing with Copper–Sandoz most of the mosses living on the trunk, branches and leaves had disappeared. The serious defoliation and die-back caused by *Phytophthora* under certain conditions could also be controlled by copper mist-blowing (TOLLENAAR, 1958a).

But apart from the control of these parasites, remarkable changes were observed to take place in the leaf canopy after 6 to 12 months mist-blowing at Fazendas Mucambo in Brazil and at hacienda Esperanza in Ecuador. The new shoots that developed after copper mist-blowing had started were longer, the leaves much larger in size and darker in colour; these leaves also showed an increased longevity. This resulted altogether in a denser, darker green, more luxuriant leaf-canopy (compare *Figures 1* and *2*).

Figure 1. Mist-blowing copper on cocoa, mainly the canopy region, with Kiekens mist-blower at Tombel, British Cameroons

Figure 2. Leaf canopy in bad shape at Tombel before mist-blowing was adopted. Compare with Figure 1 after a few years copper treatment

Since then similar effects from copper leaf application have been observed in every country where I saw this system applied.

In Costa Rica Bowman (1959) was well aware of these facts and one of the points he reported in this connection was that areas sprayed with copper have as a rule three successive shoots with all the leaves still present; in untreated areas there can only be found on average two successive shoots with leaves because the rest of the leaves have already been dropped.

When I was lecturing on this subject in Uruçuca, Brazil (Tollenaar, 1958b), Silva (1958) remarked that he had already collected data on the effect of copper leaf-spraying on cacao leaves many years ago, and that they clearly showed the favourable effect on leaf size, leaf colour, extended lifetime and longer shoots. Wallenius (1958) reported as results of copper-based mist-blowing: a more luxuriant appearance of the cacao, an increase in yield, and in addition the pods were always found to be heavier than those in untreated plots.

It is known that copper is readily absorbed by cacao leaves, but when added to the soil it becomes as a rule inaccessible to the plants (van Alphen, 1957).

The same effects from copper foliar mist-blowing have been reported on coffee in Kenya (Rayner, 1951 and *Annual Reports*, 1956 and 1957 of the Coffee Board of Kenya). These treatments are called ' Tonic copper spraying ' or ' Anti-leaf fall spraying ' and resulted in darker green leaf colour, increased longevity and a considerable (up to 300 per cent) increase in production. Medcalf and Lott (1956) published similar results obtained when coffee was fertilized with copper chelates, compounds available to the plants.

The result of copper application on cacao leaves is that it builds up a healthier, more luxuriant leaf canopy, which leads in the following years to increased production. Its effect on yield is indirect and not as immediate as yield increases brought about for example by the control of pod losses, caused by *Marasmius*, *Monilia* or *Phytophthora*.

DIRECT EFFECT OF COPPER AND ZINC SPRAYS ON POD PRODUCTION

The first experiments at hacienda Clementina to control Witches' Broom disease were carried out between 1954 and 1956 with high-volume spraying, using a Bean knapsack sprayer and treating the cropping areas of the trees, which were cuttings of ICS 1, three to five years old. This trial consisted of 4 blocks sprayed with Copper–Sandoz compared with 4 blocks untreated, as well as another 4 blocks sprayed with dithane compared with 4 blocks untreated. Each block had as an average 50 cacao trees in production.

The Copper–Sandoz and dithane concentrations used in high-volume spraying were 0·2 per cent; approximate rate of application: 1 000 litres per hectare (approximately 100 gallons per acre). This spraying resulted in a reduced setting of fruit. In the following tables the number of wilted cherelles is also given because, as Cope (1939) pointed out, increased cherelle wilt is usually occasioned by increased setting of cherelles. *Table 6* gives the result of these trials.

Table 6. Effect of high-volume spraying of copper and zinc on total pod production. Average number of pods and of wilted cherelles per tree from sprayed and unsprayed trees

Treatment	Pods produced		Cherelles wilted	
	Unsprayed	Sprayed	Unsprayed	Sprayed
Copper–Sandoz, monthly June '54 to June '55	12·95	11·03	9·34	8·04
Dithane, monthly July '55 to June '56	31·58	31·36	8·11	7·08

Similar results were obtained by Holliday (1954), who noted that whilst high-volume copper sprays reduced disease losses, they also reduced the number of pods setting to such an extent that the fungicidal benefits were outweighed by the reduction in pod setting. Renaud (1953, 1957), in West Africa, reached exactly the same conclusions; for this reason he sounded a warning at the 1957 London Cocoa Conference against the use of copper sprays shortly before and during the main flowering period. But it is not the copper content of the spray which produces the adverse effect on cropping so much as the drop size and the volume of liquid applied. It was proved that high-volume spraying of the bearing surface of the cacao tree with plain water also impaired fruit-setting; the large droplets damaged the flowers just as heavy rain disturbs flowering and fruit-setting in cacao and coffee.

The picture changed completely when mist-blowing replaced high-volume spraying. The very fine mist drops caused no damage to the flowers and part of them drifted into the canopy, where they were deposited on the leaves. This had a beneficial effect on fruit-setting, with zinc as well as with copper. *Table 7* shows the effects of mist-blowing copper and zinc compounds on to cacao in the crop-bearing parts of the tree. (Clone

Table 7. Effect of low-volume spraying of copper and zinc on total pod production. Numbers of pods and of wilted cherelles produced by mist-blowing the cropping surfaces of cacao trees

Treatment	Total pods produced		Cherelles wilted		
	Untreated	Treated	Untreated	Treated	
Copper–Sandoz, 15 day cycle					
Oct. '57 to Dec. '58	16120	18482	3164	4054	} *per same*
Ditto, 30 day cycle	9344	10182	5581	6176	} *acreage*
Dithane (zinc), 15 day cycle					
Oct. '55 to Sept. '56	63·9	71·7	12·67	21·05	} *average*
Ditto, 30 day cycle	69·8	84·9	21·59	34·40	} *per tree*

ICS 1, five to seven years old; 8 replications of treated and untreated blocks; number of trees per block approximately 40).

Without exception, fruit-setting and cherelle wilt were increased by mist-blowing copper and zinc. Copper, of course, is preferable since zinc compounds give no control of Witches' Broom, *Monilia* and *Phytophthora* pod-rot.

Thereupon an experiment was carried out with special canopy spraying on a 6-year old planting of ICS 1 at Clementina between February 1957 and December 1957. From a high tower Copper–Sandoz was mist-blown on to the top of the cacao canopy (an application of 10 gallons of 2 per cent Copper–Sandoz per acre). Little or no copper penetrated the canopy to reach the cropping parts of the trees, so that the effect of this spraying on disease control was almost negligible; but the effect on fruit-setting was remarkable. Four replications of treated and untreated blocks were used, the counts of pods and cherelles (*Table 8*) being confined to ten trees at the

Table 8. Effect of copper mist-blowing from above on to leaf canopy on pod production. Average number of pods and of wilted cherelles per tree from treated and untreated blocks

Item	Untreated	Copper leaf application
Total number of pods	23·30	31·54
Healthy pods harvested	19·46	27·86
Wilted cherelles	18·46	28·56

centre of each block. Already in the first month of spray application the cacao showed an increased number of cherelles wilted, which clearly indicates the immediate effect. Although little disease control was obtained by the canopy applications from above, the yield was increased by 43 per cent.

Marquez da Cruz (1958) arrived from observations in the Bahia cacao zone at the same conclusion, viz. that the beneficial effect of mist-blowing with copper on the yield was mainly due to an increased fruit production and only in the second place to a control of *Phytophthora* pod-rot. There mist-blowing was carried out 4 times annually with Copper–Sandoz, using Kiekens knapsack machines. His results are summarized in *Table 9*.

Siller (1954) obtained with dithane spraying in Costa Rica an increased production of 38·8 per cent, which was not due to disease control, but probably, as he stated, to ' a stimulative effect ' of the zinc.

Table 9. Effect of mist-blowing Copper–Sandoz on production of healthy pods in the cacao zone of Bahia, according to H. Marquez da Cruz

Year	Average number of healthy pods per tree produced		Increase of yield (in number of healthy pods per tree) was due to:	
	Untreated	Treated	Disease control (less pods diseased)	Increased pod production
1956	26·4	36·0	1·3	8·3
1957	18·0	27·9	1·4	8·5

ANALYSIS OF EFFECT OF COPPER AND ZINC FOLIAR SPRAYS ON POD PRODUCTION

Making a further analysis of the zinc and copper mist-blowing trials carried out at Clementina during 1955 to 1957, I found that there was only a positive effect on cherelle wilt production during the main flowering periods. There was no effect during the periods of scattered flowering.

Table 10. Effect of foliar mist-blowing of copper and zinc on production of cherelle-wilt, as influenced by intensity of flowering

During periods of	Ratio of wilted cherelles per tree treated/untreated			
	Copper–Sandoz		Dithane	
	15 day cycle	1 month cycle	15 day cycle	1 month cycle
Main flowering	2·25	1·92	1·76	2·26
Medium flowering	1·47	1·11	1·16	1·27
Scattered flowering	0·86	0·98	0·94	1·03

If the number of wilted fruit is a measure of total fruit-setting, the positive effect of foliar copper and zinc sprays on yield seems to find its origin during the main flowering periods.

This indication was confirmed when during 1958–59 flowering and fruit-setting were recorded monthly at hacienda Esperanza, Ecuador.

This was executed in an even stand of 8-year-old seedling cacao, which was divided for this purpose into two equal parts. One part was left untreated and the other part received 9 mist-blown foliar applications of 2·5 kg Copper–Sandoz per hectare from November 1957 to June 1958 and again from November 1958 onwards (at intervals of approximately 3 to 4 weeks). On ten trees in the centre of both blocks the number of flowers, small cherelles and pods harvested were counted monthly (with the exception of August and December 1958); these data are given in *Table 11*.

During the main flowering season, viz. the second half of 1958, flowering and fruit-setting (cherelles) were increased 6·5 times by copper spraying, but during the period when there was little flowering, viz. during the first quarter of 1959, the difference in fruit-setting was negligible.

Without coppper application, flower formation and fruit-setting were not only seriously reduced, they were also retarded. Flowering dragged on outside the favourable main flowering period; the impression was gained that there were plenty of flower primordia, which, however, were not able to develop all at the same time without some addition of copper.

Table 11. Effect of foliar applications of Copper Sandoz on flower formation, fruit-setting and yield

Period	Number of flowers, cherelles and pods per 10 trees					
	Number of flowers		Number of cherelles		Number of pods harvested	
	Untreated	Treated	Untreated	Treated	Untreated	Treated
June 1958	46	2132	8	47	0	0
July 1958	473	3775	8	48	0	0
Sept. 1958	550	3629	17	141	0	8
Oct. 1958	748	4352	20	153	0	20
Nov. 1958	645	2704	36	188	3	19
Total June to Nov. 1958	2462	16592	89	577	3	47
Jan. 1959	262	234	63	66	3	60
Feb. 1959	255	935	26	28	5	85
Mar. 1959	23	47	6	4	9	50
Total Jan. to Mar. 1959	540	1216	95	98	17	195
	Small pods to be harvested April to June 1959				47	30

At fazenda Mucambo, Brazil, we tried to find out in 1958 whether it was advantageous to add small amounts of zinc to the copper sprays. The indication was obtained that this increased production by an extra 5 per cent. This is in accordance with the results Ellis (1944) obtained with potatoes when adding some zinc to copper sprays. Copper alone increased production by 84 bushels/acre; when zinc was added the increase rose to 112 bushels/acre.

PRACTICAL CONSEQUENCES OF EFFECT OF COPPER FOLIAR APPLICATIONS ON FRUIT-SETTING

The direct and indirect effects of copper leaf applications on increased fruit-setting afford an explanation of why on the one hand crop region spraying, as carried out on the isle of Sâo Tomé (see *Figure 3*) has had no appreciable effect on production, but on the other hand leaf canopy spraying in Costa Rica (*Figure 4*) and mist-blowing as it has been carried out in the British Cameroons (*Figures 1* and *2*) have achieved production increases far beyond those to be expected from control of *Phytophthora* pod-rot only. In the former case McLaughlin and Bowman (1954) reported doubling of production; in the latter case Sanders (1956) obtained a tripling of yield and since then production there has further increased every year.

From all this experience in many different cacao zones of the world, it becomes obvious that *one or two foliar applications of copper annually before the main flowering period will always be economical.* They will make for abundant flowering and fruit-setting during periods when conditions are favourable and will prevent copper deficiency from hampering flowering and causing a partial shift of fruit production to less favourable periods.

Whether additional crop region mist-blowing will be economical will depend on the losses suffered from pod-rot diseases like *Phytophthora*, *Marasmius* and *Monilia*. Under conditions favourable to defoliation caused by *Phytophthora* regular leaf canopy spraying will be necessary.

Figure 3. Lance spraying of the crop region with Bordeaux mixture in São Tomé. This successfully controls Phytophthora but has a disappointing effect on production

Figure 4. Canopy spraying with Bordeaux mixture from movable aluminium pipes connected to a pipeline, Costa Rica. This has restored the canopy and more than doubled the yield

Figure 5. Mist-blowing with copper at Mucambo, Brazil, with a Kiekens knapsack machine. The nozzle is directed upwards to reach the canopy. Note luxuriant foliage after two years treatment

In all these cases it is important that the copper deposit is resistant to rain-wash in order to extend its influence over a long period. Small but highly concentrated droplets stick better; no spreader should be added. The less the droplets are able to spread the better the copper will stick. At fazenda Mucambo mist-blowing is for that reason now carried out with some 20–25 litres of a 10 per cent suspension of Copper–Sandoz per hectare. Such ultra-low-volume spraying also saves time and labour. For the purpose of canopy mist-blowing the nozzle is now fixed in an upward direction (see *Figure 5*).

In unshaded cacao plantations foliar applications can be executed by an aeroplane with ' Micron-air ' equipment; very good foliar coverage can be achieved in this way with 10 litres of 20 per cent Copper–Sandoz per hectare.

In both cases it is possible to add biuret-free urea in concentrations of 10 to 40 per cent to the copper suspension. An addition of small quantities (0·5 kg per hectare) of strongly adherent zinc (e.g. dithane) may also be advantageous.

SUMMARY

Mist-blown applications of Copper–Sandoz (monthly and half-monthly treatments) considerably reduced the number of Witches' Broom diseased pods and vegetative brooms. Dithane was not effective.

An old, heavily infected plantation, where brooms had never been removed, recovered after monthly copper mist-blowing of the canopy during the wet season (starting one month in advance of the rains). Production rose by more than 80 per cent.

High-volume spraying of the cropping region of the cacao tree involves the risk of damage to the flowers, with reduction in fruit-setting.

With low-volume spraying this risk is non-existent and, moreover, experiments show that copper applications to the leaves result in considerable increases in flowering, effective fruit-setting and pod production during the main fruiting period.

One or two foliar sprays applied shortly before a flowering period, using copper compounds resistant to rain-wash, will always be economical.

Some addition of zinc and also of biuret-free urea may often be advantageous.

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Persistency of Lactation in Cattle in Egypt

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Although the buffalo is the main source of milk in Egypt, yet the native cow predominates over buffaloes in some regions in the country. The Friesian has been introduced to Egypt on a large scale to be maintained as pure bred stock and to up-grade the native cows in an attempt to improve their milk production.

Persistency of lactation in dairy cattle can be defined as the ability of animals to maintain a high daily milk flow throughout the lactation period. It is well known that persistency of lactation is one of the main factors controlling the total milk production in dairy cattle. No reports are available on the environmental and hereditary factors affecting persistency of lactation in cattle in tropical and subtropical regions. This analysis was therefore planned to investigate such problems in Egypt.

Studying non-genetic factors influencing persistency will help in standardizing records collected under different environmental conditions. The part of the total variance in this trait which is caused by additive genes, i.e. heritability, is an important genetic parameter needed for choosing the most effective breeding method for improving persistency of lactation in dairy cattle.

MATERIAL

The data used in the present report were collected on 120 Friesian, 70 native and 90 halfbred cows belonging to the Ministry of Agriculture, and located at Gimmeza experiment station in the middle part of the Delta. More than 650 normal lactations from the three groups of cows mentioned above were available for this investigation.

Animals were fed mainly on clover during the period from November to May, and cows producing more than 30 lb of milk daily were given an extra ration of concentrates according to their excess in production. During summer and early autumn balanced concentrate rations with some green fodder were fed daily according to the weight and production of cows. Cows were hand-milked twice daily at 7 a.m. and 4 p.m.

METHOD USED FOR ESTIMATING PERSISTENCY

Different measures have been suggested and used by workers to study the shape of the lactation curve in dairy cattle. The method developed by Ludwick and Petersen (1943) was applied to our data.

The procedure used for deriving the formulae for the three groups of animals was as follows. The average lactation period was 371, 309 and 238 days for Friesians, halfbreds and native cows respectively. Since it was found that the maximum daily milk production was in general attained

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in the sixth and seventh weeks after calving, the first 28 days of the lactation were excluded and only the remainder of the lactation period considered, as representing approximately the declining phase. This period was divided into four equal parts, each of which (rounded off to the nearest whole week) consisted of 84 days for the Friesians, 70 days for the halfbreds, and 56 days for the native cows.

Milk production during each of these four periods was designated X_1, X_2, X_3 and X_4 respectively (*Figure 1*). The proportionate rate of decline in its earliest phase may be represented by the ratio X_2/X_1, and similarly in later phases by X_3/X_2 and X_4/X_3.

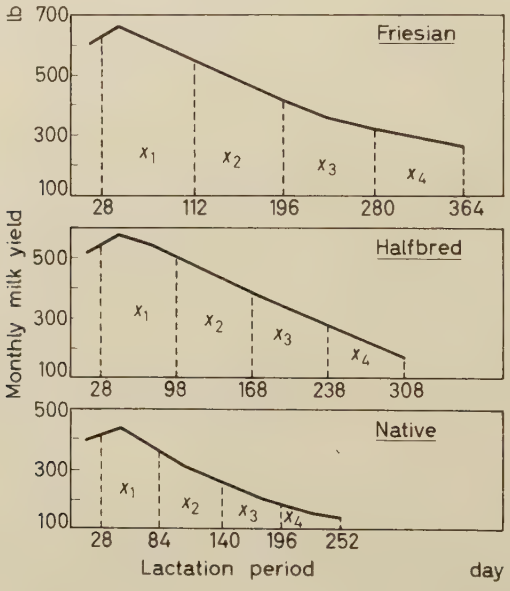

Figure 1. Theoretical divisions of the lactation curve

Such ratios should be multiplied by factors according to the relative importance of the levels of production at different stages of the lactation period. The factors derived from our data and used for weighting the three ratios were:

0·340 : 0·333 : 0·327 for Friesian
0·360 : 0·330 : 0·310 for halfbred
and 0·349 : 0·333 : 0·318 for native cattle.

Thus, the formulae used for calculating the persistency were:

Friesian: $0{\cdot}340\ X_2/X_1 + 0{\cdot}333\ X_3/X_2 + 0{\cdot}327\ X_4/X_3$
Halfbred: $0{\cdot}360\ X_2/X_1 + 0{\cdot}330\ X_3/X_2 + 0{\cdot}310\ X_4/X_3$
Native: $0{\cdot}349\ X_2/X_1 + 0{\cdot}333\ X_3/X_2 + 0{\cdot}318\ X_4/X_3$

METHODS OF ANALYSIS

Analysis of variance, correlation and regression were the statistical techniques used in studying the influence of environmental factors on persistency of lactation (Snedecor, 1956). The correlation between the possible

combinations for the first four lactations (Lush, 1947) was the method used for estimating the repeatability of persistency. The correlation between half-sibs (Lush, 1949) was applied for calculating the heritability of this trait.

RESULTS

Age at first calving

To study the effect of age at first calving on persistency of lactation, heifers were classified into six groups with a six-month interval (*Table 1*).

Table 1. Effect of age at first calving on persistency

Group	Friesian		F_1		Native	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
Below 24 *mo.*	3	0·7810	8	0·6808	4	0·6167
24 –	24	0·6712	19	0·5295	8	0·6318
30 –	24	0·7251	29	0·6735	20	0·6069
36 –	17	0·7074	12	0·7527	13	0·6713
42 –	9	0·8228	4	0·7822	14	0·5975
Over 48	5	0·6357	1	0·9757	4	0·6130
Total and av.	82	0·7207	73	0·6853	62	0·6225

It can be seen that age at first calving has no definite effect on persistency of lactation in the three groups of cattle studied. Moreover, analysis of variance showed that differences between the six groups in persistency of lactation were not statistically significant and the *F* values obtained were 1·15, 0·99 and 0·29 for the Friesian, halfbred and native cattle respectively. The regression coefficients of age at first calving on persistency of lactation were also found to be not significant. These results are in accordance with those obtained by Asker and Miss Bedeir (1958a,b) on buffaloes.

Age

The effect of age in terms of lactations on persistency was studied for the first five lactations for the three groups of cattle and results obtained are presented in *Table 2*.

Table 2. Effect of age on persistency

Order of lactation	Friesian		F_1		Native	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
First	82	0·7154	73	0·6901	62	0·6225
Second	76	0·7098	55	0·6992	54	0·5698
Third	49	0·7334	40	0·7127	42	0·5756
Fourth	33	0·7374	27	0·6170	25	0·5417
Fifth	21	0·7255	20	0·7253	16	0·6021

It can be observed that the Friesian and the halfbred animals attained the highest values in persistency during the fourth and fifth lactations respectively. First calvers, however, were the highest in this respect in native cattle. Studying the differences between the persistency indices for the five lactations for the parents and their first cross revealed that differences between values obtained were not statistically significant,

Moreover, the correlation coefficients between age in terms of months and persistency within lactation were found non-significant and amounted to −0·013, 0·211 and 0·114 for the Friesian, halfbred and native cattle respectively.

Sana Allah (1952) reviewed the work on the effect of age on persistency of lactation in dairy cattle and showed that persistency of lactation in European breeds decreases as cows advance in age and heifers surpass older animals in this respect. Our results on the Friesian and the F_1 do not support these findings but those on native cattle are in agreement in this respect.

Calving interval

The effect of calving interval on persistency of lactation was investigated using two methods. The first is shown in *Table 3*, in which calving intervals were grouped into classes with one month class interval.

Table 3. Effect of calving interval on persistency

Class intervals	Friesian		F_1		Native	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
Below 330 *days*	11	0·5945	7	0·6335	25	0·5341
360	21	0·6305	15	0·5868	39	0·5507
390	23	0·6863	16	0·5915	23	0·6799
420	29	0·7008	11	0·7701	20	0·6745
450	27	0·7593	13	0·7240	13	0·6727
480	14	0·7890	6	0·7692	11	0·6801
510	9	0·7769	6	0·7387	5	0·7263
540	9	0·8023	4	0·8446	4	0·6834
570	8	0·7803	6	0·8459	7	0·7871
600	11	0·8486	—	—	—	—
630	7	0·7126	—	—	—	—

Examination of *Table 3* indicates that increase in the length of calving interval was accompanied by gradual increase in the persistency of cows. It can also be observed that the first class in the halfbred only was higher in their persistency indices than the second one.

The second method was by estimating the correlation between the two items. The number of observations available for such study was 191, 138 and 147 for Friesians, F_1 and native cattle respectively. The correlation coefficients obtained were 0·254, 0·279 and 0·272 for the three groups in the same order and these correlations were significant (P=0·01). Such results indicate that calving interval is an important factor affecting persistency of lactation in dairy cattle. Ludwick, Petersen and Fitch (1943), Sikka (1950) and Mahadevan (1951) demonstrated that increasing calving interval was responsible for increasing persistency of lactation. Asker and Miss Bedeir (1958a,b) reported similar results on buffaloes.

Month of calving

Number of cows calving at different months as well as their average persistency indices for the three groups of cattle are shown in *Table 4*.

Table 4. Effect of month of calving on persistency

Month	Friesian		F_1		Native	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
Jan	36	0·6571	28	0·6147	20	0·5179
Feb	17	0·6982	29	0·6101	16	0·5444
Mar	13	0·7375	23	0·6195	25	0·5718
Apr	20	0·7069	9	0·6481	16	0·5270
May	15	0·7187	9	0·7262	11	0·7000
Jun	13	0·8824	10	0·8630	10	0·7994
Jul	8	0·7953	9	0·7997	19	0·6208
Aug	13	0·8419	6	0·8550	7	0·4082
Sep	8	0·8425	19	0·8027	16	0·6275
Oct	29	0·7526	20	0·7602	16	0·7053
Nov	33	0·6892	22	0·7069	23	0·5666
Dec	25	0·6457	31	0·6457	21	0·5399
Total and av.	240	0·7197	215	0·6907	200	0·5892

The trend of persistency as shown in this table indicates that variation between months is noticeable. Analysis of variance carried out proved that differences between months were significant ($P = 0·01$) for the Friesian and the first cross, and F values obtained were 4·83 and 5·41 respectively. For the native cattle differences between months lack statistical significance ($F = 2·41$).

In order to study the effect of season of calving on persistency cows were grouped into two classes. The first group includes cows calved between October and March and the second includes cows calved between April and September (*Table 5*). Results obtained show that cows calving during autumn and winter were lower in persistency than those calving during spring and summer months.

Table 5. Effect of season of calving on persistency

Season of calving	Friesian		F_1		Native	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
Autumn and winter	163	0·6888	153	0·6531	121	0·5904
Spring and summer	77	0·7848	62	0·7833	79	0·6179

Analysis of variance between the two groups as well as within groups in persistency illustrates that differences found were statistically significant except in the case of native cattle which lack significance.

These results are not in agreement with those reported on dairy breeds in temperate countries. Gaines (1927), Johansson and Hansson (1940), Sikka (1950) and Mahadevan (1958) have shown that cows calving during summer months were lower in their persistency than animals calving during winter. Asker and Miss Bedeir (1958a,b), on the other hand, found that there was no significant difference between buffaloes calving during summer and winter in Egypt.

Lactation period

The effect of the length of the lactation period on persistency of lactation for the three groups was studied, and results obtained are shown in *Tables 6*

and 7. It can be seen from *Table 6* that the correlation coefficients between the two items were highly significant for the Friesians, crossbred and native animals. The strongest correlation was found with the Friesians while the lowest was obtained for the native cows.

It was of interest to calculate the persistency indices for the three groups of cattle according to the length of lactation using a 30 days class interval

Table 6. Correlation between lactation period and persistency

Breed	*No.*	*Mean of L.P.*	*Mean of P.*	*r*
Friesian	240	373 *days*	0·7204	0·568
F_1	196	309 *days*	0·6877	0·702
Native	183	217 *days*	0·5851	0·906

(*Table 7*). It can be observed that increasing the length of the lactation period was accompanied by an increase in the persistency of lactation.

There are two reports available on the effect of the lactation period on persistency of lactation in dairy animals, and both are in close agreement with our findings. Sana Allah (1952) has shown that there is a close relationship between the lactation period and persistency studying the records of 134 Holstein cows of the University of Minnesota herd. Asker and Miss Bedeir (1958a,b) analysing the records of two herds of buffaloes in Egypt concluded that the lactation period was one of the most important factors affecting persistency of lactation and the correlation coefficient between the two variables was 0·726.

Table 7. Effect of lactation period on persistency

Class intervals	*Friesian*		F_1		*Native*	
	No.	*Av. persis.*	*No.*	*Av. persis.*	*No.*	*Av. persis.*
Below 140 *days*	—	—	—	—	19	0·1256
170	—	—	3	0·2310	22	0·3264
200	4	0·2447	5	0·3125	41	0·5267
230	9	0·4712	11	0·4182	54	0·6349
260	19	0·5862	30	0·5397	30	0·7658
290	26	0·6583	52	0·6014	24	0·8704
320	43	0·6679	39	0·7618	5	0·7958
350	39	0·7081	22	0·8323	4	0·8549
380	20	0·7846	24	0·8427	—	—
410	20	0·8774	14	0·8436	—	—
440	21	0·8294	3	0·7540	—	—
470	8	0·7448	5	0·8544	—	—

Dry period

Table 8 shows the effect of the preceding dry period on persistency of lactation for the Friesians, native and crossbred cattle.

The correlation coefficients presented in *Table 8* lack statistical significance. When the previous dry period was grouped into classes with one month class intervals, it was found also that persistency did not show a definite trend. These findings indicate that the dry period has no effect on persistency of lactation for the three groups of cattle studied.

These results are in accordance with those found by Gooch (1935) studying the effect of the preceding dry period on persistency of lactation in dairy cattle and Asker and Miss Bedeir (1958a,b) on buffaloes. Sanders (1930) and Johansson and Hansson (1940) reported different results and showed that increasing the length of the preceding dry period was responsible for increasing the persistency indices of dairy cattle.

Table 8

Breed	*No.*	*Mean of dry period*	*Mean of persis.*	*r*
Friesian	179	98 *days*	0·7231	−0·004
F_1	142	119 *days*	0·6910	0·150
Native	137	179 *days*	0·5702	−0·050

Repeatability and heritability of persistency

In studying the repeatability and heritability of persistency of lactation, records collected on the Friesian, F_1 and native cows were grouped together because of the small number available for such study in each group. *Table 9* shows the correlation coefficients obtained for the lactations correlated. The average correlation coefficient for the whole data was 0·196.

It is interesting to note that there is a tendency for the correlation coefficients to be greater for consecutive lactations than that of the records separated by longer time. Such a finding may be attributed to differences in feeding and management during the longer period between non-consecutive lactations. The negative correlation coefficient obtained between the first and fourth lactation is probably due to sampling error.

The repeatability estimate of persistency for cattle in Egypt is very close to that reported by other workers in temperate countries. Johansson and Hansson (1940) in Sweden and Mahadevan in Scotland (1951) found the repeatability of persistency to range between 0·13 and 0·24. Sikka (1950),

Table 9. Repeatability of persistency

Lactations correlated	*No.*	*Coefficient of correlation*
First and second	157	0·268
Second and third	118	0·314
Third and fourth	77	0·262
First and third	112	0·230
First and fourth	68	−0·240
Second and fourth	75	0·094
Total and average	607	0·196

however, appears to be the only author to report that about half the total variance in persistency is due to variation from one lactation to another. Asker and Miss Bedeir (1958a,b) studied the repeatability of this characteristic in Egyptian buffaloes and reported an estimate of 0·224 which is very close to that found for cattle in the present analysis.

Twelve sires having 123 daughters were available for calculating the heritability of persistency and the value obtained was 4·1 per cent. Such an estimate is lower than those reported by Johansson and Hansson (1940),

Sikka (1950), Mahadevan (1951), and Sana Allah (1952) who demonstrated that about 15 to 30 per cent of the total variance in persistency is due to genetic differences between individuals. Moreover, Asker and Miss Bedeir (1958a,b) found heritability of persistency of lactation in buffaloes to be 23 per cent which is very close to that reported on dairy cattle.

DISCUSSION

The low milk production of native cattle is one of the main problems of dairying in tropical and subtropical regions. The total milk yield of dairy animals, however, is actually influenced by the maximum initial production, the persistency of lactation and the length of the lactation period. The persistency with which high daily milk production is maintained is considered the most important factor affecting the total milk yield.

The present report includes a study of the effect of several factors on persistency of lactation in native, Friesian and halfbred cows in Egypt. The influence of the preceding dry period, lactation period and calving interval on persistency of lactation in animals studied was similar to that reported by other workers on standard breeds of dairy cattle in temperate countries. Results obtained on the effect of age and month of calving on this characteristic in Egypt for the Friesian and F_1 cows are not in agreement with those found by other workers abroad.

Mahadevan (1958) discussed variation of milk yield with age in European cattle in tropical and subtropical countries. It has been found that maximum production was attained in temperate countries by the fifth lactation, while standard breeds of dairy cattle in the tropics attain peak production during the third or the fourth lactation. He attributed this difference to environmental factors under tropical conditions and to the old age at first calving for pure breeds in the tropics. Such circumstances may be responsible for the peculiar results obtained on the effect of age on persistency of lactation for the Friesian in Egypt.

Results obtained on the effect of month of calving on persistency for the Friesian and the halfbred cows indicate that summer calvers surpass winter calvers in persistency. Such findings may be due to the fact that both groups of cattle have a long lactation period and those calving during summer months graze clover all the season. In other words, such animals have a better chance to graze and produce during the milder season of the year than those calving late in winter. Native cows calving in summer, on the other hand, do not have this chance because of their short lactation period which amounted to 217 days only compared to 373 days and 309 days for the Friesians and halfbred respectively.

This analysis showed that the Friesian cattle were the highest in their persistency indices while the native cows were the lowest in this respect. The halfbred cows were intermediate between the two parents as far as persistency is concerned. Persistency values obtained were 0·7539, 0·6910 and 0·5865 for the Friesian, halfbred and native cows respectively. It should be noted, however, that differences between the three groups in this respect were highly significant (F=7·748). Coefficients of variation of persistency for the three groups in the same order mentioned above were 22·8, 25·1 and 40 per cent.

Sana Allah (1952) estimated the persistency of lactation for a Friesian herd in the U.S.A. as 0·7776 compared with 0·7154 found for the Friesian in Egypt for the first lactation. Differences between the two values obtained for the same breed, using the same procedure, were statistically not significant. El-Itriby and Asker (1958) have shown that the native cows in Egypt were inferior in milk yield to the Friesians and crossbred animals maintained under the same conditions. The low milk yield of native cows is due to the low initial milk production coupled with low persistency and short lactation period.

The estimate obtained as to the repeatability of persistency in this report indicates that about one fifth of the total variance in this character is due to variation from one lactation to another. The heritability of persistency was found to be very low and amounted to 4 per cent only. In other words, most of the variation in this trait is not of genetic origin and can be attributed to environmental factors. Workers abroad have reported higher estimates for the heritability of persistency. Of course, the number of half-sibs utilized in the present work was very limited and it is to be expected that heritability estimates for a given character differ from one population to another. However, the heritability for persistency shown in this work denotes that improving the standard of husbandry, as well as applying better breeding systems, will lead to improving this character in dairy cattle in tropical and subtropical countries.

SUMMARY

Milk records of Friesian, native and halfbred cows belonging to the Ministry of Agriculture were used for developing a measure for persistency of lactation for each group of cattle. The data utilized included 280 cows having more than 650 lactations. The effect of different non-genetic factors on persistency was investigated. The repeatability and heritability of persistency of lactation were also estimated.

It was found that age at first calving had no significant effect on persistency of lactation for the three groups of cattle studied. The same results were obtained when the effect of dry period on persistency was investigated.

Highest persistency indices were obtained during the fourth, fifth and first lactations for the Friesians, halfbred and native cows respectively. It has been shown, however, that differences in persistency values between cows at different lactations were not statistically significant.

Month of calving influenced persistency of lactation significantly for Friesians and halfbred animals only. This analysis indicates that cows calving during spring and summer months were higher in persistency than those calving during winter and autumn.

Studies on the effect of calving interval and the length of the lactation period on persistency showed that increasing the length of these two factors was responsible for increasing the persistency indices. High positive correlation coefficients were obtained between the two items and persistency.

Repeatability and heritability of persistency were found to be 0·196 and 4 per cent respectively.

The Friesian cows were superior to halfbred and native cattle in persistency and native cows were the lowest in this respect.

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A Preliminary Reassessment of Diatraea saccharalis *(F.) in Barbados, West Indies*

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Even after many years control work the moth-borer, *Diatraea saccharalis* (F.) is still the most important pest of sugar cane in Barbados, probably causing a loss of between 5 000 and 10 000 tons of sugar per annum. Since 1929 it has been the policy of the Department of Agriculture to mass-rear and liberate the egg parasite *Trichogramma minutum* Riley to augment the natural *Trichogramma* population at a time when it is increasing too slowly to control *Diatraea*. In recent years, 300 to 350 million *Trichogramma* have been distributed annually. Periodic attempts (all unsuccessful) were made to introduce the well known Tachinid larval parasites *Lixophaga diatraeae* Townsend, *Metagonistylum minense* Townsend, and *Paratheresia claripalpis* Wulp., and also the Braconids *Ipobracon grenadensis* Ashmead and *Agathis stigmaterus* Cresson.

The *Trichogramma* campaign was initially very successful. Between 1930 and 1934 joint infestation dropped from 33·5 to 13·5 per cent (Tucker, 1935), and has remained more or less at that level ever since. However, as it has been shown in Antigua (Box, 1932), in Louisiana (Jaynes and Bynum, 1941) and in Trinidad (Simmonds, 1951) that *Trichogramma* releases are often superfluous in view of the numbers already present in the field, it was decided to carry out a survey over several years to determine the true level of *Diatraea* infestation, and to assess as far as possible the effectiveness of *Trichogramma* releases as a factor in its control. The results that follow were obtained from the first year of work in 1958.

LEVEL OF DIATRAEA INFESTATION

Sampling method

Factory yard counts of bored joints have been used for many years in determining the level of infestation in Barbados. During the 1958 crop season 61 samples were taken from factories throughout the Island, each sample consisting of 100 canes taken haphazardly from a load. Each cane was examined for external damage only.

The errors arising from non-random sampling and poor counting are important. It was noticed that the five people regularly engaged on the factory yard counts sometimes gave very different values for the joint infestation of any one load. Since each observer recorded his counts separately it was possible to compare the individual estimates for 30 samples on which all five had been working together. In an analysis of variance the differences between observers were highly significant ($P = < 0{\cdot}001$). A

summary of the results (*Table 1*) shows that B's counts were far below those of the other four. This may be in part due to his missing some bored joints, but also to his picking out longer (and therefore sounder) canes. B's results were therefore discarded. Although an analysis of variance showed that the remaining counts by A, C, D and E differed significantly ($P = < 0{\cdot}001$) they had to be used without further adjustment. The net effect is probably an underestimation of the joint infestation of every sample.

Table 1. Joint infestation—individual estimates

Observer	*No. of bored joints*	*Total No. of joints examined*	*Percentage joint infestation*
A	1 551	10 859	14·3
B	989	13 589	7·3
C	1 397	12 346	11·3
D	1 546	11 453	13·5
E	1 580	12 963	12·2

Cane joint infestation

Average joint infestation was 12·35 per cent. A summary of the results of the survey is given in *Table 2.*

Table 2. Joint infestation—summary

Category	*Material*	*No. of samples*	*Percentage joint infestation*
Crop	*Plant canes*	24	12·9
	Ratoons	22	11·2
Varieties	*B.37161*	8	14·3
	B.41211	16	13·6
	B.45151	9	9·6
	B.4744	13	10·8
Trichogramma	*With liberations*	28	11·4
	Without liberations	18	13·2

The differences between each category of cane were small, and an analysis of variance showed that only the varietal differences were significant ($P = < 0{\cdot}025$). B.45151 showed an appreciably lower infestation. Differences between plants and ratoons, and areas with and without *Trichogramma* liberations, were not significant. The effect of rainfall was not easy to determine as the data for each area were confounded with varieties (*Table 3*). B.37161 and B.41211 (high average infestation) were most common in the intermediate, and B.45151 and B.4744 (low average infestation) in the high rainfall area, but there were not enough samples to make it clear whether the level of infestation was primarily determined by rainfall or variety.

Table 3. Joint infestation—rainfall and varietal effects

Rainfall area	*High*		*Intermediate*		*Low*	
Variety	*No. of samples*	*Percentage joint infestation*	*No. of samples*	*Percentage joint infestation*	*No. of samples*	*Percentage joint infestation*
B.37161	4	14·2	6	15·0	2	10·8
B.41211	3	10·7	10	13·9	4	15·3
B.45151	8	9·5	1	9·7	—	—
B.4744	9	11·4	5	12·2	1	7·3
Average		11·45		12·7		11·1

The joint infestation results as they stand for each category are not really comparable. They are based on the infestation per 100 canes, so no account is taken of such factors as the number of canes per acre in each variety or the number of joints per cane in different crops and rainfall areas. For instance, if variety A has 1·5 times as many canes per acre as variety B, then, for the same *Diatraea* population per acre, the joint infestation of A will be 2/3 that of B. Conversely, if the joint infestation for A and B is the same, then A must be supporting 1·5 times as many *Diatraea* per acre as B. Only from consideration of data of this type will the true varietal differences be apparent.

B.45151 has more canes per acre than B.37161. Consequently, the difference in susceptibility is actually smaller than would appear from the counts. Also, B.45151 has thinner canes than B.37161. These, when bored, are more liable to snap and rot in the field. Badly bored canes would therefore tend to be excluded from the counts. The net effect is that the difference between these two varieties is magnified.

It is clear that factory yard counts do not give a fair picture of *Diatraea* infestation. Even year-to-year comparisons are invalid unless the counts are made by the same observers. Canes must be picked at random, and also accurate account taken of field losses and the growth characteristics of each class of cane.

TRICHOGRAMMA SURVEY

Trichogramma *liberations*

In Barbados cane is planted in November, and is harvested 14 to 16 months later. In plant canes most *Diatraea* damage occurs in the ' critica stage ' between May and September (Tucker, 1934a). In February and March parasitism by *Trichogramma* is negligible, and by April has only reached 7·8 per cent (Tucker, 1935). Therefore, from March to September laboratory reared *Trichogramma* are liberated, mostly in plant cane fields, to augment parasitism by the natural *Trichogramma* population.

In most years all plant cane should receive about 5 000 *Trichogramma* per acre per month. In fact, distribution of parasites is uneven as only 2/5 of the plantations collect their quota regularly. This is to some extent

compensated by doubling the *Trichogramma* quota for these estates, so that the net effect is that about 1/2 the plant canes should receive *Trichogramma* at the rate of 10 000 per acre per month. 1958 production was below normal so that on the estates which did collect their parasites all plant canes and some ratoons should have had 2 000 per acre per month in April, rising to 4 000 by May, and continuing at that level until September. There is, however, no guarantee that these numbers are actually liberated. Some estates conscientiously collect their quota each week, but the parasites never reach the fields.

Sampling method

It was planned to determine the effect of *Trichogramma* liberations on *Diatraea* oviposition and *Trichogramma* parasitism under field conditions. For this purpose, 28 fields which covered the three rainfall areas were selected. 14 were on estates known never to liberate *Trichogramma*, and would therefore be free from liberated *Trichogramma* apart from any which might drift in from neighbouring estates. The other 14 were on estates where *Trichogramma* was released regularly, but to make doubly sure the Departmental staff were responsible for releases in these experimental fields. As the cane grew up, fewer fields could be examined in the time available, so that in August counts were being made in only eight fields. Egg counts were restricted to three plots, each of ten cane plants, which were selected from every field.

Every cane plant in the plots was examined leaf by leaf once a week. In the early stages of the survey all egg clusters found were tagged with red wool, and picked off the following week, by which time most of the eggs would have hatched. This was unsatisfactory since many of the clusters were lost without leaving any identifiable trace. It was then decided to pick off clusters which had hatched, been eaten, or otherwise killed, and to tag only those which had not hatched. Tagged clusters were brought in the following week. If they had not hatched by then they were kept in the laboratory another week to determine whether or not they were dead. (The laboratory conditions were too dry and probably caused a higher mortality amongst parasitized clusters than would have occurred in the field.) All clusters were examined with a binocular microscope, and the condition of the eggs was recorded.

There are considerable disadvantages in estimating the number of eggs per acre from counts of this type. First, the distribution of *Diatraea* eggs through a field of cane is very patchy so that the results from small plots could lead to quite erroneous conclusions. However, the use of three plots per field will to some extent allow for this. Secondly, the human error in collecting the clusters can be very large, but it would be impossible to quote an exact amount, varying as it must do from hour to hour and from day to day with different individuals. When oviposition was low, with perhaps only one or two clusters in 30 plants, there is no doubt that the error was frequently 100 per cent or more, but against this there was always the likelihood that a cluster missed one week would be found the next.

Provided, however, these sources of error are kept in mind, it is possible to derive useful information from these counts. *Diatraea* oviposition and

Trichogramma parasitism could be followed week by week for six months, a period which covered most of the normal *Trichogramma* releases, and also one month before any but natural *Trichogramma* were in the fields.

Results

The most obvious feature of the counts was the individuality of different fields even in a small area. Oviposition in three fields on one estate ranged from 10 000 to 100 000 per acre in one particular week and, while *Trichogramma* was most common in one field, *Prophanurus alecto* Crawford accounted for almost all egg parasitism in the next.

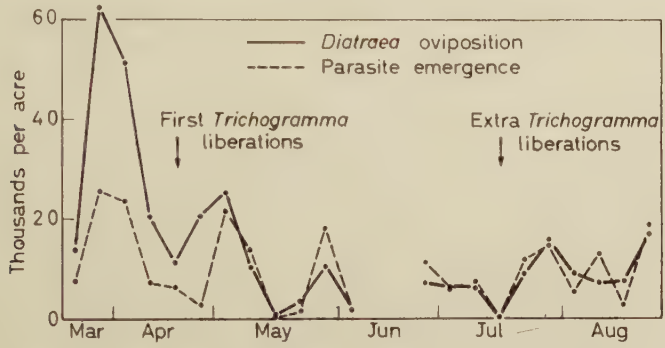

Figure 1. Stable Field; high rainfall; with Trichogramma *liberations*

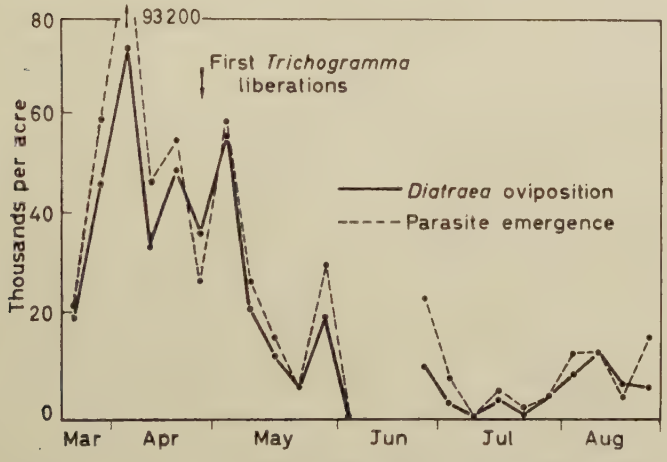

Figure 2. Upper Green Bottom; high rainfall; with Trichogramma *liberations*

Many egg clusters were destroyed, specially in the dry months from March to May, before either *Diatraea* or parasites emerged. Ants were the chief predators, but mites were occasionally seen. In the data which follow only eggs which produced living parasites were recorded as being parasitized. Eggs which were parasitized and were then destroyed or which died in the laboratory were recorded separately. The number of emerging

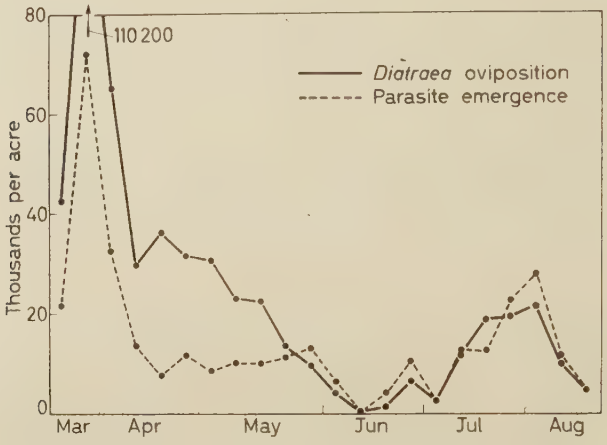

Figure 3. Swamp Field; high rainfall; no Trichogramma *liberations*

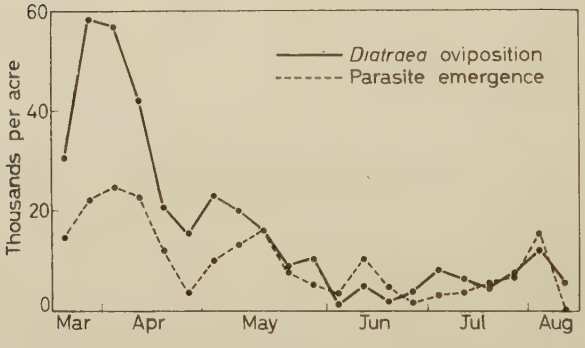

Figure 4. Woodhouse Field; high rainfall; no Trichogramma *liberations* (Prophanurus alecto *Crawford predominant*)

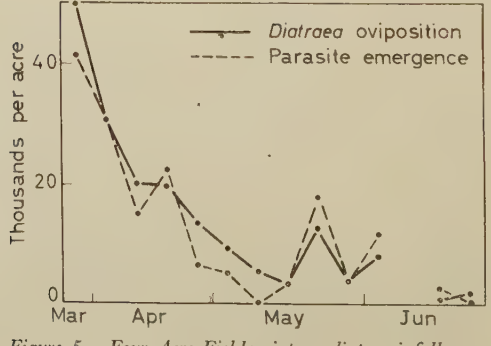

Figure 5. Four Acre Field; intermediate rainfall; no Trichogramma *liberations*

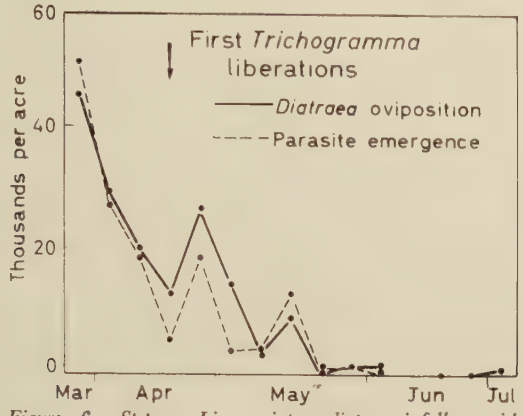

Figure 6. Stepney Line; intermediate rainfall; with Trichogramma *liberations*

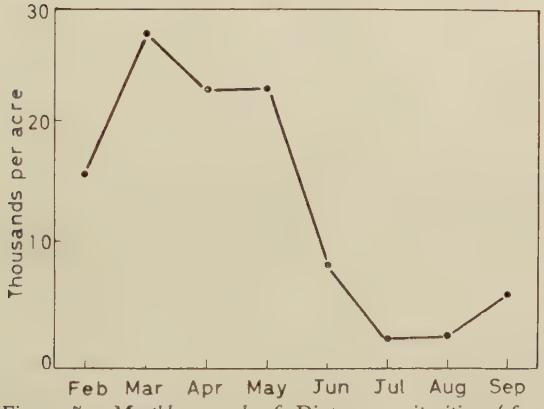

Figure 7. Monthly record of Diatraea *oviposition (from* Tucker, 1934a)

parasites was calculated on the basis that on average 2·6 *Trichogramma* or 1·0 *Prophanurus* hatch from a single *Diatraea* egg. Tucker (1933) found only 1·78 *Trichogramma* emerging from a single egg, but the value 2·6 agrees very closely with Box's (1932) estimate of 2·5 in Antigua.

(a) Diatraea *oviposition*—The general pattern of the oviposition rate is shown in *Figures 1* to *6* which give weekly records of *Diatraea* oviposition and emergence of egg parasites, being at its peak in March and April, dropping to a minimum in May and June, and increasing slightly in July and August. Oviposition was highest in the high and intermediate rainfall areas, reaching 110 200 per acre in a week in one field (cf. Tucker, 1933, who gives 27 600 per acre per *month* as the maximum for the whole Island). In the low rainfall area the highest oviposition recorded was 23 000 per acre per week.

This pattern is probably true for most years, being observed in 1933 (Tucker, 1933) (*Figure 7*) and also in the varietal plots where oviposition rates have been followed for many years. Oviposition followed the same course in colonized (*Figures 1, 2* and *6*) and uncolonized (*Figures 3, 4* and *5*)

fields and the sudden drop in April and May occurred in most fields before the effect of *Trichogramma* liberations could have been felt. It is, therefore, a seasonal fluctuation, and is not, as TUCKER (1935) states, due to *Trichogramma* liberations.

(b) *Egg parasitism*—Egg parasitism prior to the first *Trichogramma* liberations in April was 43·2 per cent and increased as the season progressed, reaching 64·2 per cent in August in colonized and uncolonized fields. Incidental observations showed that parasitism was of a high order as early as February. The effect of *Trichogramma* liberations (*Table 4*) was negligible. Parasitism

Table 4. Effect of Trichogramma *liberations on egg parasitism*

Month	*Colonized fields*			*Uncolonized fields*		
	No. eggs examined	*No. of fields*	*Percentage parasitism*	*No. eggs examined*	*No. of fields*	*Percentage parasitism*
Mar	13 099	14	45·2	11 716	14	40·9
Apr	15 983	14	35·65	12 653	14	33·0
May	5 741	12	53·1	6 618	11	42·6
Jun	836	12	65·2	1 386	11	60·2
Jul	1 711	12	51·5	2 189	6	61·6
Aug	1 450	3	56·8	2 046	5	69·4
Total No. eggs examined	38 820			36 608		

was slightly higher in colonized fields in April, May and June, but actually lower in the months that follow. 20 000 *Trichogramma* per acre per week were liberated in July and August in one field in the high rainfall area. Despite this, parasitism fell slightly and *Diatraea* oviposition rose appreciably (*Figure 1*).

In March and April at the peak of *Diatraea* oviposition a very large number of *Trichogramma* and *Prophanurus* were emerging (*Figures 1* to *6*), 50 000 to 60 000 per acre per week being observed in some fields in the high and intermediate rainfall areas. In the low rainfall area, with lower oviposition rates, *Trichogramma* emergence stood at 7 000 to 30 000 per acre per week. In May and June it fell throughout the Island, but rose again in July and August (*Figures 1* to *4*).

DISCUSSION

It is clear that the status of *Trichogramma* has altered entirely since liberations began in 1929. Between 1929 and 1933 average parasitism in April was 7·8 per cent (TUCKER, 1935), but in March 1958, before any *Trichogramma* were liberated, it was 43·2 per cent. *Table 5* compares TUCKER's (1934a) data for *Diatraea* oviposition rate, egg parasitism and the natural *Trichogramma* population in a single uncolonized field with those obtained from a number of uncolonized fields in the same (intermediate) rainfall

Table 5. Diatraea *and* Trichogramma *in uncolonized fields*

Month	1933			1958			
	Diatraea *eggs/acre*	*Percentage parasitism by* Trichogramma	*Natural* Trichogramma *per acre*	*No. of fields examined*	Diatraea *eggs/acre*	*Egg parasitism per cent*	*Natural egg parasites per acre*
Feb	16 236	8·0	1 299	—	—	—	—
Mar	27 605	6·1	1 684	10	57 900	37·6	50 000
Apr	23 120	11·5	2 660	5	63 900	29·8	44 500
May	23 412	31·9	7 465	3	29 200	38·3	26 300
Jun	8 608	32·9	2 832	3	9 300	49·6	12 000
Jul	2 424	18·75	454	1	8 700	32·4	6 900
Aug	2 769	32·8	908	—	—	—	—
Sep	6 079	52·0	3 161	—	—	—	—

area in 1958. The 1958 counts did not begin until the third or fourth week in March, so that the *Diatraea* oviposition and the parasite population data shown for that month are lower than they actually were. The 1933 *Trichogramma* population was apparently based on 1·0 *Trichogramma*/egg, although Tucker himself (1933) had previously recorded 1·78. The 1958 results were based on 2·6 *Trichogramma*/egg. It can be seen that not only *Diatraea* oviposition but also the level of parasitism especially in March and April were much higher than in 1933. In addition there was a 150 per cent increase in the number of *Trichogramma*/egg, so the net result was that the *Trichogramma*+*Prophanurus* population was many times greater than before.

In March and April with *Trichogramma* emergence in tens of thousands per acre per week, adding a mere 5 000 per acre per month would seem pointless. But the position is less clear in May and June when, with *Diatraea* oviposition at its lowest ebb, the numbers of *Trichogramma* emerging and being liberated approach more closely. *Table 6* (from Tucker, 1935) shows that *Trichogramma* liberations in 1934 raised the level of parasitism in one experimental area by as much as 32·2 per cent (the level of parasitism was low due to the unusually dry weather). Also, in 1933, the level of parasitism in 40 colonized fields was higher than in a single uncolonized field (Tucker, 1934b). However, a comparison of colonized and uncolonized fields in 1958 (*Table 4*) shows that percentage parasitism increased independently of liberations, and in fact in July and August was slightly higher in the uncolonized fields examined. Furthermore, in the 1958 crop the difference in joint infestation between colonized and uncolonized fields, although not very reliable, was not significant, the average difference being only 1·8 per cent.

The experiment where a field was swamped with *Trichogramma* at the rate of 20 000 per acre per week in July and August is of particular interest.

Table 6. Level of Trichogramma *parasitism in 1934 (from* Tucker, 1935)

Month	*Percentage parasitism by* Trichogramma	
	Colonized	*Uncolonized*
Mar	8·3	7·1
Apr	15·5	3·4
May	11·3	6·9
Jun	27·5	11·6
Jul	57·4	25·2
Aug	51·2	22·0
Sep	31·8	14·3

Diatraea eggs were outnumbered by *Trichogramma*, the oviposition rate varying between 0 and 22 000 per acre per week. Here it might be expected that parasitism would reach nearly 100 per cent, and be followed by a severe fall in oviposition. In fact, neither occurred; parasitism fell slightly to 40 to 50 per cent, and the oviposition rate fluctuated but did not show a prolonged fall.

From these results it is clear that *Trichogramma* is now so abundant early in the season that no advantage could be gained from *Trichogramma* liberations. The evidence from egg counts and joint infestations suggests that although *Trichogramma* is scarcer from May onwards, liberations do not do anything to reduce the *Diatraea* population, even if the field is swamped with an excess of *Trichogramma*. It appears that (as Wolcott, 1943, says) the maximum control possible under any conditions is already being exerted by the natural *Trichogramma* population, and that further control is limited by the inability of the parasites to find the host at low densities.

Dugas (1939) showed that natural parasitism of *Diatraea* by *Trichogramma* in Louisiana had increased over a period of years. Tucker's (1935) data for parasitism in April rose from 0 in 1929 to 16·3 per cent in 1933. In 1958 the equivalent amount was 34·5 per cent. There is therefore the possibility that in Barbados, as in Louisiana, natural parasitism has increased due to the introduction of new strains of *Trichogramma*.

SUMMARY

The joint infestation of the 1958 crop was estimated from factory yard counts. Differences in infestation between varieties were significant; differences between fields with and without *Trichogramma* liberations and between plant canes and ratoons were not significant. The errors inherent in the sampling method were such that a true picture of infestation could not be obtained.

The method used to estimate the weekly *Diatraea* oviposition and the natural *Trichogramma* population is described, and details are given of a comparison between fields with and without *Trichogramma* liberations.

It is shown that the status of *Trichogramma* has changed completely since liberations began in 1929; the natural *Trichogramma* population is considerably higher than before, and liberations did not appreciably increase egg parasitism.

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The Effect of Post-emergence Applications of MCPB on Groundnuts

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The results of non-replicated preliminary field trials carried out by Morris (1956) at the Imperial College of Tropical Agriculture indicated that 4–(4–chloro–2–methylphenoxy) butyric acid (henceforth referred to as MCPB) offered promise as a selective weedkiller in a number of tropical crops including groundnut (*Arachis hypogea*). In general, pre-emergence applications of this material appeared to give better weed control than post-emergence applications, and the results of subsequent, replicated experiments to determine the response of groundnuts to sprays applied between planting and emergence have already been reported (Rosher and Sheldrick, 1959).

However, the selectivity of MCPB is very pronounced and it might, when used as a post-emergence spray, provide the means of controlling specific weed species of local importance in groundnuts. The experiments reported below were, therefore, designed to investigate the effects of post-emergence applications of MCPB on groundnuts, in an effort to determine the highest dose which can be applied without adversely affecting the crop.

A PRELIMINARY EXPERIMENT TO DETERMINE THE EFFECT ON GROUNDNUTS GROWN IN BOXES OF APPLICATIONS OF MCPB MADE THREE AND A HALF WEEKS AFTER EMERGENCE

Morris reported from non-replicated trials that no deaths were caused by doses of MCPB as high as 15·0 lb/ac when applied to groundnuts three weeks after emergence. He suggested, from estimates of dry weight, that plant vigour might be stimulated by doses up to 1·9 lb/ac and concluded that the highest dose tolerated by the crop would be in the region of 2 to 3 lb/ac.

An experiment was carried out in an attempt to confirm this. The range of doses of MCPB applied and the mean plant dry weights two weeks after spraying are shown in *Table 1*.

Table 1. Effect of MCPB, applied 3½ weeks after emergence, on mean dry weight of groundnut plants

Dose of sodium MCPB (lb/ac)	*Mean dry wt/plant (g) two weeks after spraying*
Control	2·23
0·23	2·90
0·47	2·42
0·94	2·54
1·88	2·46
3·75	2·19
7·50	1·80
15·00	1·26

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The sprays were applied in a dilution with water equivalent to 85 gallons of solution per acre, by making timed deliveries with a carefully calibrated hand-sprayer which was fitted with a pressure gauge.

The chemical was applied to three and a half weeks old plants of South African bunch groundnut, in boxes 18 in. × 17 in. × 4 in., and each treatment was applied to one box containing 36 plants growing in a mixed and sieved soil collected from the top 6 in. of a soil-type classified as a St Augustine loam (Chenery, 1952).

Both before and after spraying, the boxes were placed at random in groups of four in metal trays, and water was supplied, as required, by sub-irrigation. Small applications of sulphate of ammonia were made regularly to each box and BHC dust was applied as a routine precautionary measure.

RESULTS

No deaths were recorded in any of the boxes and this confirms the finding of Morris (1956) that doses as high as 15·0 lb/ac are not lethal to groundnuts. However, plants sprayed with 7·0 and 15·0 lb/ac MCPB showed severe necrotic spotting of the leaves and corky lesions of the stem. Small doses appear to cause some stimulation of plant growth during the two week period immediately following the application of the spray (*Table 1*). The results also suggest that the limit of crop tolerance may be in the order of 3 to 4 lb/ac MCPB rather than the 2 to 3 lb/ac suggested by Morris.

AN EXPERIMENT IN BOXES TO DETERMINE THE EFFECT UPON GROUNDNUTS OF APPLYING MCPB AT DIFFERENT TIMES AFTER EMERGENCE AND WITH VARYING AMOUNTS OF WATER APPLIED ON THE DAY OF SPRAYING

In an attempt to find how crop tolerance might be affected by varying the time of application of the spray and by the incidence of rainfall shortly after spraying, a number of treatments were selected as follows:

(*a*) Dose of sodium MCPB 0·16 lb/ac
0·38 lb/ac
0·94 lb/ac
2·25 lb/ac
5·53 lb/ac

(*b*) Time of spraying 1 week from emergence
2 weeks from emergence
3 weeks from emergence

(*c*) Surface watering ('rainfall') on the day of spraying None
Light (½ in.)
Heavy (2½ in.)

The 45 treatment combinations were combined in two replications of a 5 × 3 × 3 factorial in which each plot consisted of 25 plants of South African bunch groundnut grown in boxes in which the conditions were identical with those described in the previous experiment. Twelve extra boxes were also observed although the observations recorded were not included in the statistical analyses. None of these boxes were sprayed with MCPB

but pairs of them received one of the possible combinations of light or heavy watering applied one, two or three weeks after emergence.

The spray was applied by passing the boxes at constant speed beneath a stationary nozzle fed from an Oxford Precision Sprayer. The volume applied was equivalent to 49·5 gallons per acre, due allowance having been made for lack of uniformity of spray distribution across the width of the wetted area.

After spraying, the boxes were transferred to metal trays housed in an open-sided building roofed with two thirds glass and one third corrugated metal. Water was supplied by sub-irrigation. Sulphate of ammonia and BHC dust were applied as in the previous experiment.

Rainfall was simulated by applying water from a watering-can fitted with a fine rose. The application of $2\frac{1}{2}$ in. of water was spread over a period of approximately four hours and the application of $\frac{1}{2}$ in. spread over a period of approximately one hour. The spray was allowed to dry on the leaves of the groundnuts before the water was applied, but the method of watering was such that entire plants were wetted.

RESULTS

No plants were killed by any of the treatments but increasingly severe morphological changes were produced by doses of 2·25 and 5·53 lb/ac. Plants were stunted and suffered from corky lesions of the stem, due to proliferation of xylem and cortical tissue rupturing the epidermis, and also showed necrotic spotting of the leaves due to evaporation of spray droplets leading to local toxic concentrations. Entire plants were stiffer and more leathery to handle, and leaves sprayed while the lamina was still small, remained small and became spatulate rather than elliptic. Such spatulate leaves often displayed a mottling of light and dark green in various patterns, usually the darker colour being more distal and peripheral, the lighter proximal and central with a mottled zone between. Sometimes, the leaf margin was also crinkled or rolled down. The 5·53 lb/ac dose retarded flowering for two to three weeks except when applied three weeks after emergence. With the exception of the necrotic spotting, these symptoms are similar to those observed in groundnuts sprayed before emergence

Table 2. Effect of MCPB, applied after emergence, on mean dry weight of six weeks old groundnut plants

Dose of MCPB lb/ac	*Dry wt/plant 6 wks after emergence (g)*	*Per cent of 'control'**
0·16	4·95	98·3
0·38	5·16	102·4
0·94	4·82	95·7
2·25	4·60	91·3
5·53	3·59	71·3
Least sig. diff. P=0·05	0·544	—
Least sig. diff. P=0·01	0·715	—

* 'Controls' consisted of boxes none of which were sprayed with MCPB but which, collectively, received all combinations of surface watering and time of application thereof.

(ROSHER and SHELDRICK, 1959), and also similar to the effects of MCPB on peas (JASMIN and LYALL, 1957).

The analysis of variance of the means of the dry weights per plant sampled at six weeks after emergence, shows that the main effects of ' time of spraying ' and ' watering on day of spraying ' were not significant, but the response to varying the dose of MCPB was highly significant. This is shown in *Table 2.* It is interesting to observe, once again, an indication that application of 0·38 lb/ac stimulated growth. Doses up to 2·25 lb/ac had only a limited effect upon dry weight but 5·53 lb/ac MCPB reduced dry weight by a significant amount.

The interaction between the ' time of spraying ' and the ' dose of MCPB' was also highly significant and the results are summarized in *Table 3.*

Table 3. Effect of interaction between dose of MCPB and its time of application on mean dry weight of six weeks old groundnut plants

Time of spraying, weeks after emergence	*Dose lb/ac sodium MCPB*				
	0·16	0·38	0·94	2·25	5·53
1	5·26 * (104%)	5·75 (114%)	4·78 (94·9%)	4·51 (89·5%)	2·77 (55·0%)
2	5·18 (103%)	4·56 (90·5%)	4·72 (93·7%)	3·89 (77·2%)	3·60 (71·5%)
3	4·42 (87·8%)	5·16 (102·0%)	4·97 (98·7%)	5·41 (107%)	4·40 (87·4%)
Least significant interaction [*P*=0·05] 0·944 *g*					
Least significant interaction [*P*=0·01] 1·24 *g*					

* Values shown above are mean plant weights in grammes. Data in parentheses represent the values above them expressed as percentages of controls which received no spray.

From *Table 3* it can be seen that the effects of incremental doses of MCPB above 0·94 lb/ac applied three weeks after emergence are small in comparison with the effects of similar incremental doses applied either one or two weeks after emergence. These differences are large enough to demonstrate significance of the interaction.

The dry weight of plants sprayed with 0·16 lb/ac three weeks after emergence is low compared with plants similarly sprayed when one or two weeks old, but the difference, in this case, is not large enough to show a significant interaction.

From a general consideration of the main effects together with the interactions, it is clear that the tolerance of groundnuts, grown in boxes, to post-emergence applications of MCPB, is greater at three weeks than at one or two weeks after emergence. Approximately 1 lb/ac may be applied safely to plants one or two weeks old, but 5½ lb/ac only just exceeds the limit of crop tolerance when the spray is applied three weeks after emergence. The application of water on the same day as spraying, but after the spray has had time to dry on the leaves, does not appear to increase or decrease the effect upon the crop.

A FIELD EXPERIMENT ON THE EFFECT ON GROUNDNUT OF APPLICATIONS OF MCPB MADE AFTER EMERGENCE

This experiment was designed to test, in the field, the results obtained from the trials carried out in boxes. The treatments used and the yields obtained are shown in *Table 4*.

Table 4. Effect of various doses of MCPB applied after emergence, upon yield of sun-dried groundnuts weighed in the shell

Treatment	*Yield lb/ac*
Not weeded	350
Hand-weeded as required	1650
0·5 *lb/ac MCPB, 1 week after emergence*	1540
1·0 *lb/ac MCPB, 1 week after emergence*	1610
1·0 *lb/ac MCPB, 2 weeks after emergence*	1280
2·0 *lb/ac MCPB, 2 weeks after emergence*	1170
2·0 *lb/ac MCPB, 3 weeks after emergence*	1500
4·0 *lb/ac MCPB, 3 weeks after emergence*	1570
6·0 *lb/ac MCPB, 3 weeks after emergence*	939
Least significant difference (P=0·05)	508
Least significant difference (P=0·01)	669

Four replications of the nine treatments were used in a randomized block experiment on a soil type classified as a River-Estate Fine Sand (Chenery, 1952). The plots were located upon cambered beds separated by box drains 25 ft apart, and the groundnuts were planted 5 in. apart and 1 in. deep in ridges 26 in. apart running across the beds. A single ridge between adjacent plots was used as a guard-row, and the harvested area of each plot was approximately 1/116 ac. Before planting, each plot received 3·0 lb of a fertilizer mixture of equal parts by weight of sulphate of ammonia, muriate of potash and triple superphosphate.

The sprays were applied by making timed applications with an Oxford Precision Sprayer and the total volume delivered on each plot was equivalent to 22 gallons of solution per acre.

Although the area was carefully prepared, weeds were present in abundance even before the first spray was applied. The species which predominated were the grasses *Chloris radiata* (L.) Swartz, *Leptachloa scabra* Nees, *Eriochloa punctata* (L.) Desv., *Eleusine indica* (L.) Gaertn. and *Panicum fasciculatum* Willd. and it was recognized, from observations made elsewhere, that post-emergence applications of MCPB would not control these weeds, which showed signs of smothering the groundnuts. It was, therefore, decided to hand-weed immediately before spraying and to confine all observations to the response of the crop but, in error, those plots that were sprayed one week after emergence were hand-weeded two days after spraying instead of two days before. All the remaining plots which received MCPB were hand-weeded two days before the application of the spray. To ensure, as far as possible, that the measured responses were not affected by weed growth, individual plots sprayed with MCPB were again hand-weeded as soon as it appeared that the weeds might interfere with the crop.

About six weeks after planting the weather became very dry, and from then until the crop was harvested, approximately 1 in. of water was applied each week through an overhead irrigation system.

For reasons already explained, observations were made only upon the response of the crop.

It was observed that doses over 1·0 lb/ac caused some degree of mottling of the leaves and doses over 2·0 lb/ac caused spotting of the leaves and corky lesions of the stems, irrespective of the time of spraying. The severity of the symptoms increased with increasing dose. Only on those plots sprayed with 6·0 lb/ac MCPB was the vigour of the crop visibly reduced.

The crop was harvested fourteen weeks after planting and the yields of sun-dried nuts, weighed in the shell, are shown in *Table 4*.

When considering the results of this experiment it must be borne in mind that weed control was obtained by hand hoeing, even in the plots that were sprayed with MCPB. Differences in yield, therefore, largely reflect the response of the crop itself to the applied doses and not the response of a crop–weed complex and, in view of the findings from the previous experiments, the results are largely as expected (see *Table 4*). The application of 0·5 or 1·0 lb/ac MCPB one week after emergence, or of 2·0 or 4·0 lb/ac 3 weeks after emergence did not depress yields compared with plots which were hand-weeded but not sprayed, but 6·0 lb/ac applied three weeks after emergence reduced the yield significantly. The considerable, but non-significant, depression in yield following application of only 1·0 lb/ac two weeks after emergence is puzzling and is probably not a true effect of treatment in view of the fact that no yield depression was caused by 1·0 lb/ac applied only one week after emergence. 2·0 lb/ac applied two weeks after emergence depressed yields as expected.

The very low yields obtained from the plots in which the weeds were allowed to develop unchecked provide an indication of the extremely severe degree of weed infestation experienced and justified the decision to hand-weed just before spraying.

CONCLUSIONS

Within the range of conditions under which the experiments were conducted, groundnuts show a tolerance of 1·0 lb/ac MCPB applied one to two weeks after planting or 4·0 lb/ac applied three weeks after planting, and wetting the plants to simulate rainfall after spraying has little effect upon the response of the crop, provided the spray has dried upon the leaves. However, since these results have, in the main, been obtained from plants growing in boxes, more work is required before field recommendations can be made, but it is suggested that this information might be used as the basis for the design of further field experiments in which yield is used as the main criterion of crop response.

From observations made in these and other experiments, it is suggested that a post-emergence application of MCPB at the rate of 4·0 lb/ac may offer control of the following weed species: *Euphorbia hirta* L., *Phyllanthus* spp., *Crotalaria incana* L., *Portulaca oleracea* L., *Amaranthus* spp., *Merrimia aegyptia* (L.) Urban, and *Spigelia anthelmia* L.

The development of the following weed species may be temporarily suppressed by the post-emergence application of 4·0 lb/ac MCPB: *Euphorbia geniculata* Ortega, *Caperonia palustris* (L.) St. Hil., *Euphorbia hypericifolia* L., and *Cleome aculeata* L.

The following species appear to be resistant to the post-emergence application of 4·0 lb/ac MCPB: *Mimosa pudica* L., *Alternanthera* spp., *Cyperus rotundus* L., *Eleusine indica* (L.) Gaertn., *Rottboellia exultata* (L.) Kuntze, *Chloris radiata* (L.) Swartz, *Leptachloa scabra* Nees, *Eriochloa punctata* (L.) Desv., and *Panicum fasciculatum* Willd.

SUMMARY

A series of experiments to test the effects of applications of MCPB on groundnuts is described.

From the growth rate of plants grown in boxes it is determined that 0·94 lb/ac MCPB can be applied safely to groundnuts one or two weeks after emergence or between 2·25 and 5·53 lb/ac three weeks after emergence. The application of water to simulate rain on the same day as spraying, but after the spray had dried upon the leaves, had no apparent effect upon the response of the crop. An indication of growth stimulation was obtained as the result of applying doses in the order of 0·25 lb/ac at any time between one and three weeks after emergence.

Results of a field experiment show that 1·0 lb/ac MCPB applied one or two weeks after emergence does not depress the yield of groundnuts that are kept clean by hand weeding and that 4·0 lb/ac applied three weeks after emergence also had no effect on yield. 6·0 lb/ac MCPB applied three weeks after planting is shown to cause a very serious reduction in yield.

A list of weed species likely to be controlled or appreciably suppressed by the post-emergence application of 4·0 lb/ac MCPB is given.

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The Effects of Arboricides on East African Trees and Shrubs—III

Combretum *and* Commiphora *Species*

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Since 1953, the Colonial Pesticides Research Unit has been engaged in a programme of research into the potentialities of arboricides for the control of woody plants in East Africa. The investigations have covered a wide range of species commonly encountered when bush is cleared for tsetse control or grassland improvement and the present article gives the results of the trials conducted on various species of *Combretum* and *Commiphora.*

These two genera are represented by large numbers of species widely distributed throughout much of the African continent and occur as important constituents of many types of deciduous woodland and thicket. *Combretum* species include small trees, shrubs and climbers while *Commiphora* species are mostly small trees, many of them spiny. Both genera are of importance in East African tsetse habitats. *Combretum guenzii*, *C. zeyheri* and *Commiphora pilosa*, for example, are described as major components of *Glossina morsitans* habitats in parts of Tanganyika (E.A.T.T.R.R.O., 1955) while, in other parts, *Commiphora schimperi* and *Combretum zeyheri* have been recorded as the dominant trees (Tanganyika, 1955). *Commiphora schimperi* and *C. fischeri* communities have also been found to support the tsetse *G. swynnertoni* (Lloyd, 1935) and frequent mention of species of *Combretum* and *Commiphora* is made by Buxton in his discussion of tsetse and vegetation (Buxton, 1955).

The wood of many *Combretum* species is hard so that the larger trees are not easy to fell. Their main objectionable feature, however, is their ability to regenerate from the stump after cutting and many species also produce root suckers. The regeneration of *Combretum* species generally grows rapidly and, where many of these trees occur in tsetse clearings, the regrowth often needs cutting back every few years to maintain the effectiveness of the clearing. *Combretum* regeneration, although much less of a problem than the regrowth of *Acacia* species (Ivens, 1958), can also be troublesome in pastures. The young shoots have some value as browse for cattle but the coppice and sucker growth is very persistent and, unless grazing is carefully controlled, can develop into thickets which greatly reduce the grazing potential of the land (van Rensburg, 1948).

Most *Commiphora* species have relatively soft wood and are easy to fell. After cutting, coppice growth normally develops from the stump and some species, such as *C. schimperi*, produce root suckers. Regrowth, however, is not generally as rapid as with *Combretum.*

EXPERIMENTAL METHODS

The series of experiments described was carried out in various parts of Tanganyika during 1953 to 1955 and, with most trials, observations on the

effects of treatment have been continued for two years. The main chemicals tested were 2,4,5-T (2,4,5-trichlorophenoxyacetic acid) and 2,4-D (2,4-dichlorophenoxyacetic acid) applied as basal-trunk sprays or to stumps by methods described in the earlier papers in this series (Ivens, 1958, 1959). In addition, ammonium sulphamate and Monuron [*N*-(4-chlorophenyl)-*N'*, *N'*-dimethylurea] have been tested on a more limited scale. Ammonium sulphamate was applied either as a basal spray of an aqueous solution or in the form of crystals piled on the surface of freshly cut stumps. Monuron was used in aqueous suspension applied as a basal spray or sprayed on the ground around the base of the tree to cover a circle two to three feet in diameter.

RESULTS

(a) Combretum *species*

(*i*) Combretum zeyheri *Sond.*—The greatest range of chemicals has been tested on *Combretum zeyheri*, a small tree growing to a height of about 25 ft (15 to 20 ft in the experimental area), common as a co-dominant in several types of Tanganyika woodland and suckering freely from the roots when cut.

The results of several experiments carried out near Arusha in the Northern Province are summarized in *Table 1*. The 2,4,5-T and 2,4-D sprays were applied in August, the early part of the long dry season, before the trees had started to lose their foliage. The ammonium sulphamate and Monuron treatments were applied at the end of the dry season, in October, when the trees were in a state of maximum defoliation and only bore 10 to 20 per cent of their full complement of leaves. Many of the trees possessed a small number of shoots up to 3 ft high, growing from the base of the trunk or appearing from the ground a few inches away, and these were cut before the sprays were applied.

The effects of basal sprays of 2,4,5-T and 2,4-D in diesel oil became evident within a few weeks of spraying. The leaves turned yellow and fell and 10 weeks after treatment the majority of the treated trees were completely defoliated. Untreated trees, meanwhile, lost approximately half their leaves as a result of the dry conditions. Trees which lost a high proportion of foliage as a result of spraying did not produce new leaf-growth during the subsequent rainy season. The trunks remained normal in appearance for a considerable period, however, and desiccation of the bark was not observed on many trees until 10 months after spraying. Regrowth from the treated trees was first observed after 7 months and with some trees had reached a height of up to 3 ft after 10 months. The stumps regenerated more quickly. A few shoots had appeared after 10 weeks and were 4 to 5 ft high after 10 months.

The concentrations of 2,4-D and 2,4,5-T used in this trial were 1·25, 2·5 and 5·0 per cent (w/v) of acid and each was applied to a group of 10 trees. There were no consistent differences between the effects of the different concentrations and, in order to simplify the table, the percentage kills are expressed as means of the numbers affected by all three concentrations. It is evident that the most effective treatment was the ester (*n*-butyl) formulation of 2,4,5-T in diesel oil applied to frilled trunks. This chemical gave a 97 per cent kill of the aerial parts of the trees and only one third of those affected produced regrowth (new shoots were recorded up

Table 1. Effects of various arboricides on Combretum zeyheri. *Assessed 24 months after application*

Treatment	*Range of concentrations (per cent)*	*Per cent with dead trunk*	*Per cent dead without regrowth*
Standing trees:			
Frilled only	—	0	0
2,4,5-T ester			
In oil, frilled	1·25 *to* 5·0	97	66
In oil, no frill	1·25 *to* 5·0	79	41
In water, frilled	1·25 *to* 5·0	0	0
2,4-D ester			
In oil, frilled	1·25 *to* 5·0	93	47
Ammonium sulphamate			
In water, frilled	33 *to* 67	0	0
Monuron			
In water, applied to frilled trunk	25*g*/*tree*	90	70
In water, applied to ground	25*g*/*tree*	70	40
Stumps:			
Control	—	—	0
2,4,5-T ester			
In oil	1·25 *to* 5·0	—	57
In water	1·25 *to* 5·0	—	3
Ammonium sulphamate			
In water	33 *to* 67	—	0
As crystals	25 *to* 100 *g*/*tree*	—	10
Monuron			40
In water	25 *g*/*tree*	—	
Number of trees per treatment		10	
Volume of spray per tree		150 *ml*	
Mean basal diameter		4·9 *in.*	
Estimated trees per acre		200	
Volume of spray per acre		7 *gal*	
Chemical per acre at 1·0 per cent		0·7 *lb*	

to a distance of 2 ft from the trunk). An *iso*propyl ester formulation of 2,4-D in oil applied with preliminary frilling also gave an almost complete kill of the aerial parts but there was rather more regeneration than with 2,4,5-T.

With application to intact bark, concentration appears to be more important and the 1·25 per cent solution in oil was considerably less effective than 2·5 or 5·0 per cent. Without frilling, therefore, the average kill was somewhat lower. The emulsions of 2,4,5-T in water were completely ineffective on frilled trunks and also had very little effect on cut stumps. In oil, however, 2,4,5-T was moderately effective in preventing stump-regrowth and the effect of concentration was more pronounced with stumps than with frilled trees. A concentration of 1·25 per cent killed 20 per cent of the stumps, 2·5 per cent killed 60 per cent and 5·0 per cent killed 90 per cent.

Of the other treatments tested, ammonium sulphamate was ineffective at concentrations of 33 or 67 per cent applied to stumps or as a basal spray. It appeared slightly more promising when applied to stumps as crystals but even with 100 g per stump, as much as could be piled on the cut surface, only 20 per cent were permanently affected.

Monuron was more effective but acted very slowly. The appearance of the trees remained normal for at least 12 months and it was not until 24 months after treatment that some were observed to be dead. No deaths occurred with a rate of 5 g per tree but with 25 g, applied to the base of frilled trunks, 9 out of 10 trees were killed and only 2 of these produced regrowth. Applied at the same rate to the ground round the base of unfrilled trees or stumps, smaller numbers were killed, a surprising result which needs confirmation in view of the fact that Monuron is thought to be capable of entering plants only through the roots.

(*ii*) Combretum microlepidotum *Engl.*, C. binderanum *Kotschy and* C. ternifolium *Engl. and Diels.*—These three species are the main constituents of a type of woodland occurring on areas of red sandy soil near Morogoro in the Eastern Province of Tanganyika and supporting the tsetse *G. morsitans*. All are small trees growing to heights of 15 to 20 ft and all coppice freely on cutting.

An experiment to test the effects of basal sprays of 2,4,5-T on these species was started in September 1954, towards the end of the dry season, when most of the trees were leafless. The chemical was used at concentrations of 0·5, 1·5 and 4·5 per cent (w/v) of acid and a butyl ester formulation in diesel oil was compared with an aqueous solution of an amine (triethanolamine) salt. A group of 10 trees was selected at random for each treatment and an average of 200 ml was applied to each tree. The mean basal diameter of the trunks was 4·6 in. but many of the trees consisted of several trunks, the average being 1·8 per tree. As in the previous trial any small shoots at the base of the trees were cut before spraying.

The results of the final assessment of the trial made 24 months after treatment are in general agreement with the results of the trial on *C. zeyheri*. The oil solution of 2,4,5-T applied to frilled trunks was the most effective treatment. With a concentration of 4·5 per cent all the trees were killed and there was no regrowth, 1·5 per cent killed the aerial parts of 7 of the 10 treated trees, 6 of which did not regenerate. The lowest concentration of 0·5 per cent, however, was not sufficient to prevent new bark growing across the frill and all the trees receiving this treatment recovered. The aqueous solutions of 2,4,5-T amine were totally ineffective without frilling while, with frilling, only the 4·5 per cent concentration had any effect, killing the tops of 2 out of 10 trees but failing to stop regeneration.

More information on the comparative effects of 2,4,5-T on these three species of *Combretum* was obtained in a trial started in July 1955, at the beginning of the dry season, a short time before the onset of the seasonal leaf-fall. The chemical was used as the butyl ester at a concentration of 1·0 per cent in diesel oil and a comparison was made between application with and without frilling.

Table 2. Effects of a basal spray of 1·0 per cent 2,4,5-T in diesel oil on ten trees each of three species of Combretum. *20 months after application*

Species	*Number with dead trunk*	*Dead without regrowth*
With frilling		
C. ternifolium	10	10
C. microlepidotum	5	2
C. binderanum	2	2
Without frilling		
C. ternifolium	6	3
C. microlepidotum	5	3
C. binderanum	1	0

The effects 20 months after spraying are shown in *Table 2* from which it will be seen that the species differed considerably in susceptibility. *C. ternifolium* was the most susceptible and all the frilled trees died without producing regrowth. Without frilling, fewer trunks were killed and half of those which died produced new shoots from the base. *C. microlepidotum* was less susceptible, only half of the trunks being affected, while still smaller numbers of *C. binderanum* were killed. With the latter species the chemical induced a marked proliferation of the bark above the frill and, on most trees, the cut eventually healed. On most of the unfrilled trunks the bark appeared to be killed in the region wetted by the spray but new tissues developed below the dead layer so that these trees also recovered.

(*iii*) Combretum greenwayi *Exell.*—In a small trial on *C. greenwayi*, a much branched, evergreen tree, locally dominant on black-clay soils, this species proved highly resistant to basal prays of 2,4,5-T or 2,4-D. One year after spraying, a 3·0 per cent diesel oil solution of 2,4,5-T ester applied to frilled trunks only gave a kill of 20 per cent, and regenerating shoots from the few affected trees had already reached a height of up to 8 ft. This was the most effective of any of the treatments tested, a concentration of 1·0 per cent or application without frilling causing only temporary injury. The degree of injury caused by 2,4-D was similar to that obtained with 2,4,5-T.

(b) Commiphora *species*

(*i*) Commiphora schimperi (*Berg.*) *Engl.*—The species on which most work has been done is *C. schimperi*, a small spiny tree which produces coppice-growth and root-suckers when felled. The experiments on this species were carried out on an almost pure stand of *C. schimperi* 10 to 15 ft high at Shinyanga in the Lake Province of Tanganyika.

Standing trees. Table 3 shows the results of two trials on *C. schimperi* in which various basal treatments with 2,4,5-T and 2,4-D were applied at different times of year. The first trial was sprayed in December 1954, in the early part of the rains, when the trees were in full leaf. In the second, the treatments were applied in July 1955 when the trees were leafless early in the dry season.

It is clear from these results that *C. schimperi* is susceptible to low concentrations of 2,4,5-T ester in diesel oil applied to the base of frilled trunks. As little as 0·25 per cent was sufficient to give a complete kill of the above

Table 3. Effects of basal sprays of 2,4,5-T and 2,4-D applied at two different seasons to Commiphora schimperi

Date of treatment		*December 1954 Trees in leaf*		*July 1955 Trees leafless*	
Months after treatment		27		20	
Treatment	*Concentration per cent*	*No. of trunks dead*	*Dead without regrowth*	*No. of trunks dead*	*Dead without regrowth*
Frilled only	—	0	0	—	—
Frilled, diesel oil	—	5	2	4	3
2,4,5-T ester					
In oil, frilled	0·25	10	8	10	8
	0·5	10	8	9	4
	1·0	10	8	10	8
In oil, no frill	0·25	4	4	2	1
	0·5	2	2	3	1
	1·0	7	6	10	9
In water, frilled	0·5	0	0	—	—
	1·0	0	0	—	—
2,4-D ester					
In oil, no frill	0·25	—	—	5	4
	0·5	—	—	5	3
	1·0	—	—	9	6
Number of trees per treatment		10			
Volume of spray per tree		100 *ml*			
Mean basal diameter		4·6 *in.*			
Estimated number per acre		300			
Volume per acre		6·6 *gal*			
Chemical per acre at 1·0 per cent		0·7 *lb*			

ground parts and regrowth was only noted with about 20 per cent of the trees. (All regrowth appearing up to 2 ft away from the trunk was recorded.) Without frilling, higher concentrations were needed to produce the same degree of effect and, as an emulsion in water, 2,4,5-T was again ineffective. Ester formulations of 2,4-D were only tested on unfrilled trees but this chemical appeared to be of the same order of effectiveness as 2,4,5-T.

In general, there was little difference between the effects of treatments applied at different seasons though regeneration developed from a slightly greater number of the trees sprayed during the dry season. There was also a small difference in the rate of growth of the regeneration, the average height being 3·5 ft after 20 months with the dry season treatments and 1·9 ft after 27 months with the treatment applied during the rains.

The effects of the chemicals on *C. schimperi* developed rapidly and three months after the rainy season spraying the frilled trees were completely defoliated while the bark at the base was dry and cracking. At the same time the leaves of the trees sprayed without frilling were turning yellow and starting to fall. After 10 months many of the treated trees had fallen and the stumps had been eaten by termites.

Stumps. A separate experiment in which sprays were applied to stumps was carried out in the rainy season (March) of 1954. Three concentrations of 2,4,5-T were compared applied in diesel oil and in water, and ammonium sulphamate was also tested in aqueous solution. The sprays were applied to the stumps as soon as possible after cutting and the results after 19 months are shown in *Table 4.*

Table 4. Effects of 2,4,5-T and ammonium sulphamate applied to stumps of Commiphora schimperi. *19 months after treatment*

Treatment	*Concentration per cent*	*Per cent stumps rotted*	*Per cent dead without regrowth*
Control	—	0	0
2,4,5-T ester in oil	0·8	80	65
	1·7	100	80
	3·3	100	85
2,4,5,-T ester in water	0·8	90	55
	1·7	70	40
	3·3	95	85
Ammonium sulphamate in water	10	5	5
	20	5	5
	40	5	5
Number of stumps per treatment		20	
Volume of spray per stump		85 *ml*	
Mean diameter		2·8 *in.*	
Estimated number per acre		500	
Volume per acre		9·4 *gal*	
Chemical per acre at 1·7 per cent		1·6 *lb*	

It is evident from *Table 4* that 2,4,5-T had a similar degree of effect on stumps of *C. schimperi* as on standing trees and that ammonium sulphamate was ineffective at concentrations up to 40 per cent. Emulsions of 2,4,5-T in water, however, were considerably more effective on stumps than when applied to frilled trees and were only slightly less effective than the oil solutions. A somewhat greater amount of sucker growth followed the emulsion treatments and there was a small difference in the position of origin of the regrowth so that, with the emulsions, a greater proportion of the shoots were produced in the immediate vicinity of the stumps. Several of the decayed stumps were excavated and, with the oil treatments, it was found that sections of root from 6 in. to 2 ft long were dead. Beyond these sections, however, the roots still appeared healthy even where no suckers were present.

A final observation on this trial was made 30 months after treatment and a few months after a fire which had burnt off all the existing regrowth. Fresh regeneration was appearing profusely from the control stumps and from those sprayed with ammonium sulphamate but on the plots containing the stumps sprayed with 2,4,5-T only an occasional shoot was visible.

(*ii*) Commiphora subsessilifolia *Engl.*—In a trial on *C. subsessilifolia* sprayed at the end of the 1953 dry season when the trees were coming into leaf, this species appeared to be more susceptible to 2,4,5-T than *C.*

schimperi. With oil-based sprays applied to the base of frilled trunks, 100 per cent kill without regrowth was given by a 2·5 per cent solution (the lowest concentration tested) and also by diesel oil alone. When applied to the uninjured bark 2,4,5-T gave a complete kill but diesel oil alone only killed 50 per cent. Application of 2,4,5-T in oil to stumps also gave 100 per cent kill and no regeneration occurred.

(*iii*) Commiphora pilosa *Engl.*—Numerous *C. pilosa* were present in an experiment, started during the rains in May 1954, on a *Combretum–Commiphora–Acacia pennata* thicket community. The experimental area had been cleared a few months previously leaving a large number of stumps two to three feet high and, before spraying, the larger stumps were frilled near ground level.

Under these conditions both 2,4,5-T and 2,4,-D esters at a concentration of 2·0 per cent in diesel oil gave 90 to 100 per cent kill of *C. pilosa* and this species was the most susceptible of the trees making up the thicket. Emulsions of the same chemicals in water containing 10 per cent of diesel oil were also relatively effective and the 2·0 per cent concentrations gave kills of the order of 75 per cent. As was noted with *C. schimperi* the dead stumps were rapidly invaded by termites and, only 7 months after spraying, could be pushed over by hand to reveal a hole in the ground where the roots had also been eaten. Regeneration of *C. pilosa* was only noted with a very small proportion of the trees and was considerably less frequent than with *C. schimperi*.

DISCUSSION

As has been found with the other tree species discussed in previous papers in this series (Ivens, 1958, 1959), basal applications of 2,4,5-T and 2,4-D are most effective on *Combretum* and *Commiphora* species when oil is used as the carrier for the chemical. Even when the trunks are frilled, emulsions in water do not appear to penetrate far enough into the tissues to cause the death of the trees. On stumps, however, the present trials provide evidence that emulsions can be more effective and, with a susceptible species such as *Commiphora schimperi*, the degree of kill obtained with emulsions of 2,4,5-T was not much less than that given by oil solutions. This observation needs confirmation as, in the previously reported trials on other trees, emulsions have on occasion given unusually high kills which are at variance with their usual lack of effect. Frilling, in general, increases the kill given by the oil solutions but, with some species of *Combretum* and *Commiphora*, the increase is considerably less than with some of the larger tree species referred to in the earlier papers and moderate kills of *Combretum zeyheri* and *Commiphora schimperi* have been obtained without frilling.

Although there are considerable differences between individual species, *Combretum* species in general appear to be less susceptible to arboricides of the growth-regulator type than *Commiphora* species. Not only do the former show a greater tendency to produce regrowth from below ground after spraying but the above ground parts are affected more slowly. With species of *Commiphora* marked injury to the trunk, as shown by drying of the bark and exudation of gum, was noted only three months after treatment while, even with the more susceptible *Combretum* species, the bark above the

treated zone rarely showed signs of drying for 7 to 10 months. Although 2,4-D has been tested less extensively than 2,4,5-T, there is no evidence of any large difference between the two chemicals in their effects on species of these two genera.

As might be expected from the lower susceptibility of *Combretum*, the concentration of chemical employed is of more importance with these species than with *Commiphora*. The results suggest that a 2,4,5-T concentration of 1·0 per cent (w/v) of acid applied to frilled trunks is only sufficient to kill the most susceptible *Combretum* species, such as *C. ternifolium*, and that something of the order of 2·0 per cent is required for species such as *C. zeyheri*. With species of *Commiphora*, on the other hand, a relatively low concentration appears to be sufficient to give a high degree of kill and 0·25 per cent has been found to be no less effective than 1·0 per cent on *C. schimperi*. Higher concentrations generally appear to be required when the sprays are applied to unfrilled trees which again suggests that penetration of the bark is a limiting factor.

It is of interest that a difference in susceptibility between *Combretum* and *Commiphora* species similar to that noted in the present trials was found in the early trials with arsenic reported by Swynnerton (1936). Using arsenic pentoxide on frilled trees, *Combretum* spp. (*C. zeyheri*, *C. apiculatum* and *C. guenzii*) were not killed with concentrations up to 10 lb/gal. while various *Commiphora* spp. (including *C. schimperi* and *C. ugogensis*) were susceptible. Swynnerton also mentions that species of *Commiphora* can be killed by termites if the trunk is first ring-barked at ground level, cuts are made in the wood and a few handfuls of earth are thrown over the cuts. This supports the observations made in the present trials that the wood of *Commiphora* species affected by arboricides is readily eaten by termites. Experiments on *Combretum ternifolium* reported by Glasgow (1957) agree with the present results in showing that these trees can be effectively killed with a basal spray of 2,4,5-T in diesel oil.

The results provide no clear evidence that any particular time of year is especially favourable for applying arboricide treatments. With the *Combretum* species similar results have been obtained from treatments applied to trees in leaf at the beginning of the dry season and to leafless trees at the end of the dry season. There is a difference between the results obtained with *C. binderanum* in the present trials and those noted in a previous trial, in which considerably higher kills of this species growing in *Brachystegia–Pseudoberlinia* woodland were obtained from application at the end of the rains (Ivens, 1959). In the latter experiment, however, the trees were subject to fierce annual fires so that the experiments are not strictly comparable. With *Commiphora schimperi*, as was stated earlier, a slightly greater development of regeneration was noted with dry season treatment than with treatment during the rains and this agrees with a seasonal effect which has been noted with *Acacia hebecladoides* (Ivens, 1958). With *Commiphora*, however, the difference was too small to be of practical significance.

Although 2,4,5-T and 2,4-D do not entirely prevent the regeneration of *Combretum* and *Commiphora* species, the considerable reduction in regrowth brought about suggests that the chemicals can be of practical value as basal

trunk or stump treatments for the control of these trees. They appear particularly promising for species of *Commiphora* as, with all those so far investigated, relatively low concentrations bring about rapid death of the aerial parts of the trees and decay of the stumps is assisted by termites. With some species of *Combretum* also, such as *C. ternifolium*, chemicals appear capable of killing the trees and preventing regrowth though with species such as *C. greenwayi* they are not effective. With species of intermediate susceptibility, where the aerial parts are killed but an appreciable proportion regenerates, it is possible that a second treatment applied to the regrowth may considerably improve the degree of control at little extra cost. Such repeated treatments, however, have yet to be tested and their necessity would depend to some extent on the purpose for which the land was required.

SUMMARY

A series of experiments is described in which the chemicals 2,4,5-T and 2,4-D were tested as arboricides on various species of *Combretum* and *Commiphora* common in East Africa. Ammonium sulphamate and Monuron were also tested on a smaller scale. Ammonium sulphamate was ineffective in aqueous solution as a basal spray or applied in the form of crystals to stumps. Monuron, although its effects developed slowly, showed more promise when applied at a relatively high rate.

Species of *Combretum* varied considerably in their susceptibility to the growth-regulator arboricides but, in general, were less affected than species of *Commiphora*, the aerial parts taking longer to exhibit signs of injury and there being a greater tendency for regeneration to occur. Concentrations of 2,4,5-T of the order of 1·5 to 2·0 per cent were generally more effective on *Combretum* species than the lower concentrations. With *Commiphora* species, however, concentration appeared relatively unimportant on frilled trees and 0·25 per cent was as effective on *C. schimperi* as 1·0 per cent. On unfrilled trees higher concentrations were needed to give an equivalent degree of kill.

Less extensive tests were made with 2,4-D but the evidence available suggests that it is not much less effective.

Emulsions of 2,4,5-T ester in water or solutions of an amine salt were considerably less effective as basal trunk sprays than solutions of ester in diesel oil but, in one trial, emulsions were only slightly less effective on stumps of *Commiphora schimperi*. Frilling generally increased the effectiveness of treatment. Treatments applied to stumps prevented regeneration to about the same extent as basal trunk sprays.

Little difference between treatments applied at different times of year was noted with *Combretum* species, but with *Commiphora schimperi*, a slightly greater development of regeneration took place after treatment in the dry season than during the rains.

ACKNOWLEDGEMENTS

This series of experiments forms part of a programme of work on the action of arboricides and herbicides under tropical conditions financed by Colonial Development and Welfare funds and directed by the Colonial Pesticides Research Committee.

The author is indebted to the East African Trypanosomiasis Research Organization and, in particular, to the staff of the Central Tsetse Research Laboratory at Shinyanga, for their assistance in finding suitable sites for the experiments, for providing labour and for their hospitality on numerous occasions. The cooperation of the East African Herbarium in naming the tree species concerned is also gratefully acknowledged.

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The Effect of Cassava Mosaic Virus on the Anatomy of Cassava Leaves

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Previous investigations on the effect of cassava mosaic virus on cassava plants (*Manihot utilissima* Pohl.) have been concerned mainly with effects on yields and breeding of resistant or tolerant types (Beck and Chant, 1958; Nichols, 1950; Storey, 1939). Cours (1951) carried out an extensive investigation on the various factors involved in the effect of the virus on the host plant, but Pascalet (1932) appears to be the only worker who has studied the differences in anatomy which occur in virus-infected leaves. He found that in discoloured areas the palisade tissue was shortened, the spongy mesophyll being correspondingly increased. The fibro-vascular bundles in this tissue were disarranged, in some cases being separated from one another by only a few mesophyll cells. This caused abnormalities in the structure of the lamina which was thickened by the accumulation of vascular elements. He further stated that infected cells contained much larger plastids and that the contents were more diffuse than in normal cells. He concluded that the chlorosis results first from a loss of pigment, followed by a reduction in the number of plastids.

Certain abnormalities have been found in the internal structure of virus-infected leaves in Nigeria and the purpose of this paper is to describe our investigations on the effect of a Nigerian strain of cassava mosaic virus on the anatomy of the host plant.

MATERIALS AND METHODS

Symptomless healthy, and infected plants of a locally collected variety of *Manihot utilissima* Pohl. (No. 57179) were used in all experiments. The infected leaves on which the studies were made displayed a combination of chlorosis and distortion. Symptoms were compared in both expanding and mature leaves and serial transverse sections, 10 microns in thickness, were cut through chlorotic areas of leaves from infected plants and through approximately the same area on leaves at an equivalent stage of maturity from healthy plants. Transverse sections of stems and petioles were also prepared.

The sections were treated with a variety of stains including safranin and haemotoxylin, iodine–potassium iodide solution, and acid phloroglucin. Epidermal strips from chlorotic lesions were cleared and stained with Feulgen's reagent to differentiate the nucleus, and examined for possible intracellular inclusions that might occur as a result of virus infection.

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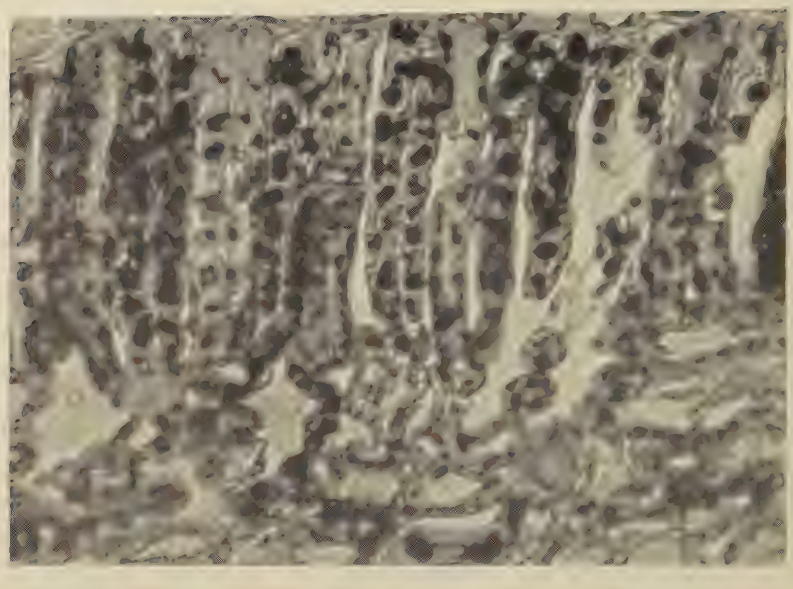

Figure 1. TS Lamina of a healthy cassava leaf showing normally developed palisade tissue and normal chloroplasts (×350; reduced 2/3 on reproduction)

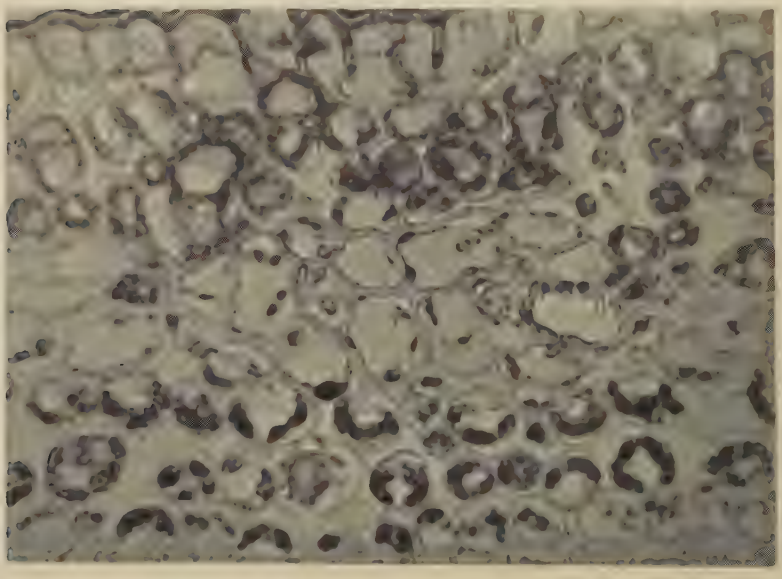

Figure 2. TS Lamina of a chlorotic area of a cassava leaf infected with mosaic virus showing undifferentiated palisade tissue and abnormal chloroplasts (×350; reduced 2/3 on reproduction)

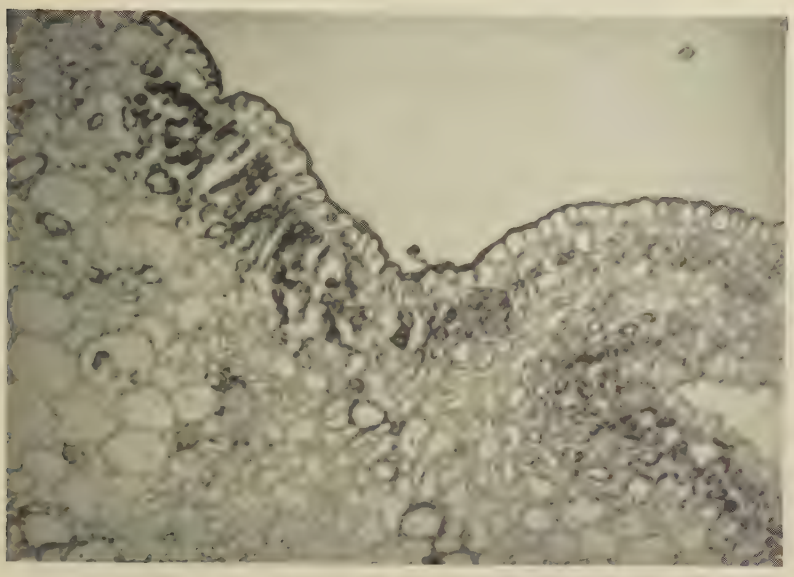

Figure 3. TS midrib and lamina of a cassava leaf infected with mosaic virus. The only normal palisade tissue is observed in part of the midrib (×100; reduced 2/3 on reproduction)

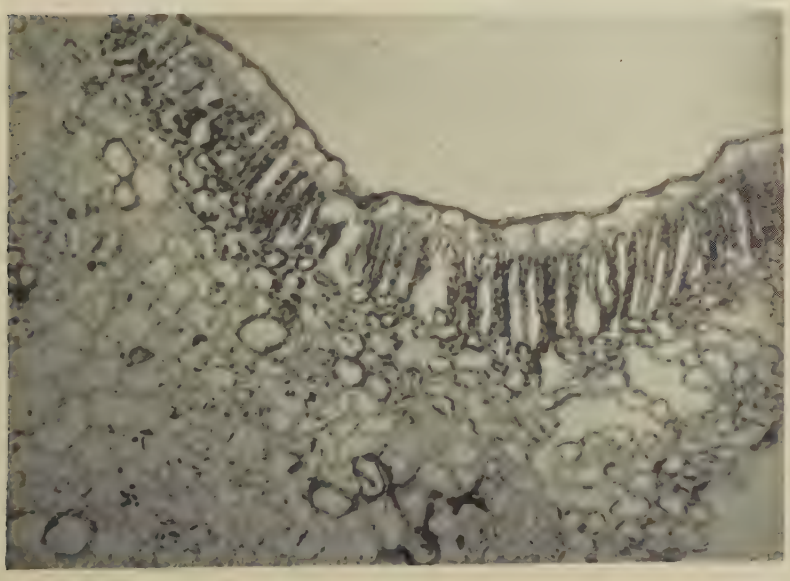

Figure 4. TS midrib and lamina of a healthy cassava leaf. The normal palisade tissue extends from the midrib into the lamina (×100; reduced 2/3 on reproduction)

ANATOMY OF HEALTHY AND DISEASED TISSUES

Sections through healthy leaves, and through the non-chlorotic areas of infected leaves showed the usual differentiation of the parenchyma into one layer of regular palisade tissue on the upper side of the leaf and a spongy mesophyll with large air spaces extending to the lower epidermis (*Figure 1*).

Sections through chlorotic areas of both immature and mature leaves showed that the mesophyll tissue is almost completely undifferentiated (*Figure 2*). Intercellular spaces are greatly reduced but there appears to be no displacement of the vascular bundles when compared with those of healthy leaves (*Figure 3*). The non-chlorotic tissue in the midrib is normally differentiated unlike the portion of lamina attached which is chlorotic. This is in marked contrast to the section of a healthy leaf shown in *Figure 4* where normal palisade tissue extends into the lamina. The chloroplasts in the undifferentiated tissue of infected leaves were fewer in number, abnormal in shape and gave a less intense staining reaction with iodine–potassium iodide solution (*Figures 1* and *2*). Reduction in number of plastids and the loss in pigmentation appeared to be associated in the development of the chlorotic leaves.

A further result of mosaic infection not hitherto described is that the phloem tissue in the midrib of the leaf is restricted to roughly circular bundles at the periphery of the xylem (*Figure 5*). This should be compared with *Figure 6* which shows the transverse section of the midrib of a healthy leaf at the same stage of development. However, there was no evidence that the phloem sieve tubes were necrotic or abnormal in any way. The sections shown in these two figures also include part of the parenchyma at the centre of the midrib. It was observed, particularly, that the starch grains of this tissue were more numerous in healthy than in infected leaves.

No differences between the phloem and parenchyma of infected and healthy leaves were observed in the petioles, and no other abnormalities were found in petioles or stems. No inclusion bodies were found in epidermal strips.

DISCUSSION

The anatomical changes in cassava leaves caused by cassava mosaic virus in Nigeria are less severe than those described by Pascalet (1932). We were unable to find the abnormal development of the fibro-vascular bundles with a corresponding decrease in the mesophyll tissue, which he described. The palisade cells of infected leaves studied by him show numerous chloroplasts aggregated in the centre of each cell but normal in shape. In the present work the chloroplasts of palisade cells in infected tissue are abnormal in shape and tend to line the cell wall. Varietal susceptibility and different virus strains are possibly the causes of these differing results.

Reduction in length of palisade cells is a typical feature of plants affected by virus diseases (Clinch, 1932). It is possible that chloroplasts are affected in mature cassava leaves but the observation that the reduction in number and less intense staining reaction occur in immature leaves suggests that the effect of infection is primarily on division of pro-plastid in the meristematic cells. When a cassava plant is infected symptoms only appear on those leaves produced subsequent to infection and never in those leaves which are

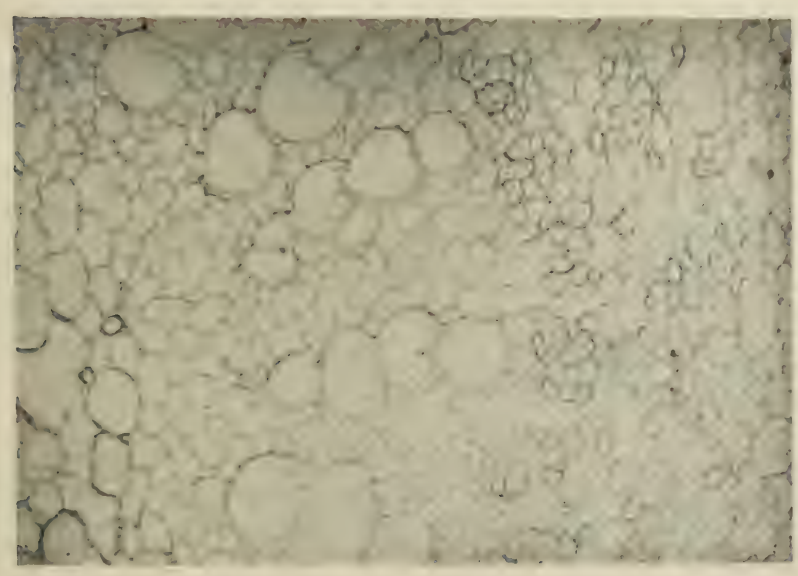

Figure 5. TS petiole of cassava leaf infected with mosaic virus showing small area occupied by phloem cells (×350; reduced 2/3 on reproduction)

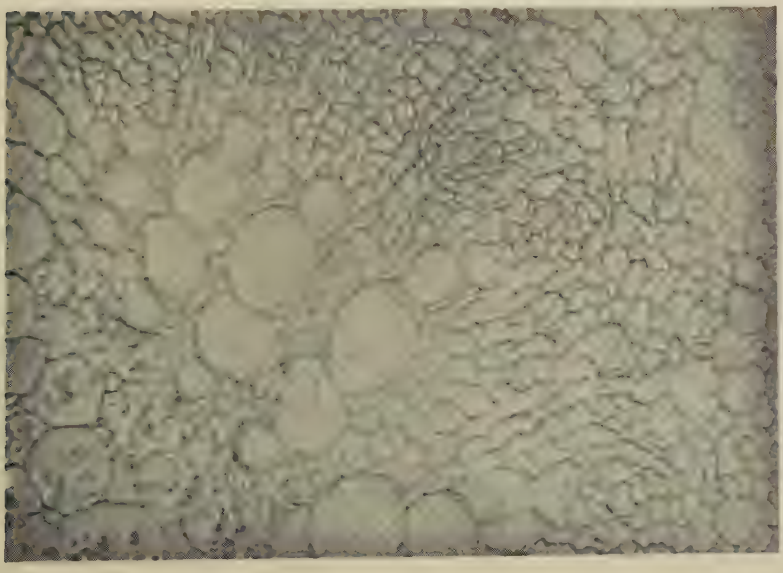

Figure 6. TS petiole of healthy cassava leaf showing normally developed phloem tissue (×350; reduced 2/3 on reproduction)

already mature. A similar sequence occurs in cacao infected with cacao swollen shoot virus, and KNIGHT and TINSLEY (1958) suggested that the anatomical changes which occur in diseased cacao leaves are caused by a failure of tissues to differentiate rather than degeneration of already differentiated tissues.

SUMMARY

Symptoms in leaves of cassava infected with mosaic virus were found to differ somewhat from those hitherto described. The palisade tissue in chlorotic lesions is undifferentiated and the chloroplasts in infected leaves are fewer in number and tend to line the cell wall. The phloem tissue in the midrib of infected leaves is restricted to small bundles although there is no evidence of necrosis of the sieve tubes. No inclusion bodies were found in the epidermal tissues of infected leaves.

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We would like to thank the Director of Agricultural Research for permission to publish this paper. We are indebted to Mr I. O. Ilodigwe for assistance in the preparation of the plant material.

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LETTER TO THE EDITOR

In his generous review of my recent book, *Insect Pests of Cotton in Tropical Africa*, Professor KIRKPATRICK mentions the lack of any reference to the source of the information given on the relation between the leaf-curl virus of cotton and its vector, *Bemisia tabaci*. This section of the book, which was drafted before the appearance of the comprehensive account given by TARR', was of course very largely dependent on your reviewer's outstanding contributions (KIRKPATRICK, 1930 and 1931) to knowledge of the subject, and I greatly regret the wholly accidental omission of these references, and the apparent discourtesy to the authors concerned.

E. O. PEARSON
Commonwealth Institute of Entomology

5 June 1959

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Book Reviews

INSECT PESTS OF COTTON IN TROPICAL AFRICA*

E. O. Pearson assisted by R. C. M. Darling. Empire Cotton Growing Corporation and Commonwealth Institute of Entomology: London, 1958. $x + 355$ *pp.* (illus.) 40*s*

We have waited a long time for this book, but it has proved worth waiting for. Moreover it is now, literally, up to date; for there are several references to articles as late as 1958, the year of publication. The publishers are to be congratulated on producing the book with such commendable promptitude. Although it is modestly stated in the Introduction that the primary source of information has been the *Review of Applied Entomology*, the book could not have been so authoritative and valuable were it not for Mr Pearson's extensive personal knowledge of African cotton pests.

There are two short introductory chapters, on 'Cotton-growing in tropical Africa' and 'Insects and the cotton plant'. In the latter, the section (pp 30–35) on the effects of insect attack on yield, a subject too often neglected, is especially valuable. These are followed by a field key to the principal disorders of cotton in Africa, covering everything from bacteria and fungi to hail and elephants. This should enable those without any technical knowledge of entomology or plant pathology (or elephants?) to diagnose any of the disorders to which cotton is subject.

Most of the book (pp 53–310) consists of accounts of the principal insect pests (including mites and millipedes). Nearly 500 species of insects have been recorded from cotton in Africa south of the Sahara, but many of these are casual and not known to cause any damage. About 150 species are dealt with, a number that includes all those that can be regarded as pests; the more important of them are very fully discussed. For instance, 36 pages are devoted to the Pink Bollworm. Special emphasis is laid on ecological aspects of the various problems, and on plant–insect relationships. Some people (certainly not this reviewer) may consider that the question of insecticides has been too briefly and cautiously treated. The need for such caution is admirably explained in an Appendix by Mr Maxwell Darling.

The eight coloured plates are of a high standard but include only Heteroptera and Lepidoptera. All except one of the 16 text figures are graphs or maps. A small criticism is that other important pests should have been figured, not necessarily in colour, and there should have been more illustrations of damage; the only existing ones are of bolls damaged by the Sudan and Pink Bollworms. But this would presumably have increased the very moderate price of £2.

Although there is a bibliography of nearly 700 references, there are nevertheless a few rather surprising omissions. Neither the present reviewer's work on *Bemisia* and Leaf Curl, nor Tarr's later booklet on the same subject (from one or both of which much of the information given must

*Please see also: Letter to the Editor, page 236.

have been derived) is quoted. The index might perhaps have been improved by sub-divisions, where a large number of page references are given under one entry. But these are trivial criticisms; the book will be found essential for entomologists and of value to all concerned with cotton-growing.—T.W.K.

NUTRITION OF THE LEGUMES

Proceedings of the University of Nottingham Fifth Easter School in Agricultural Science, 1958

E. G. Hallsworth (Ed.), Butterworths Scientific Publications: London; Academic Press: New York, 1958. *x* + 359 *pp.* (illus.) 55*s* or $10.50

This instructive and stimulating book contains 24 papers by research workers interested in the biology of legumes and nodule organisms, together with a brief record of discussions and notes on a number of demonstrations. An index of all authors referred to in the text, a plant index, and a short general index have been added.

The widespread research which has been done on the requirements for nodulation and growth of the cultivated legumes of temperate lands is comprehensively summarized in a paper (with a list of nearly 300 important references) by D. A. van Schreven, whilst an inspiring account of the physiology of nodule formation in *Trifolium* species is given by P. S. Nutman. A practical question to which one seeks an answer in these and other papers is whether the ' effectiveness ' of nodulation of a legume may be reliably judged by the amount of pigmentation, due to haemoglobin, in the nodules. The conclusion may be drawn that the presence of haemoglobin does indicate a potentially active combination of strains of host plant and *Rhizobium.* However, E. J. Hewitt's paper, which is mainly a critical review of investigations of the effects of molybdenum on legumes, cites a clear instance in which lucerne possessed healthy pink nodules and yet, for lack of molybdenum, very little nitrogen was being fixed. D. J. D. Nicholas (who reviews the biochemical aspects of nitrogen fixation in *Azotobacter*, etc., and in nodules) shows that, whereas it is evident that an enzyme containing molybdenum controls the initial reaction with molecules of nitrogen, the function of haemoglobin is not understood. It is interesting to read of a quick biochemical test of the effectiveness of *Rhizobium* strains in association with peas, in a paper by K. T. Wieringa.

T. G. Tutin outlines the characteristics of the subfamilies and tribes into which the Leguminosae are classified, and confirms that they are ' basically a tropical arborescent family '. D. O. Norris, of Queensland, briefly recapitulates his most illuminating exposition (in a paper in the *Empire Journal of Experimental Agriculture* in 1956) of the consequences of the fact that the Leguminosae originated in Cretaceous times, when hot humid conditions and old leached soils on peneplains were more widespread than they are now, and the acquisition of the symbiotic habit was presumably responsible for their successful spread. A very interesting aspect of G. Bond's paper, summarizing work done with the use of isotopic nitrogen and by other means on the function of nodules on the roots of certain non-legumes

(formed by organisms that may be Actinomycetes), is that some of these plants are shown to have been of great importance in nature as colonizers of infertile land, particularly that left by retreating glaciers, because of their fixation of nitrogen.

In his 1956 paper, NORRIS showed some of the defects of the general idea that the more specialized *Rhizobia* of the common temperate legumes could be regarded as distinct species, whilst the less specialized strains associated with tropical legumes formed only a group unworthy of being given a specific name. Papers by H. L. JENSEN and P. MANIL deal with the problems of the evolution of the *Rhizobia* and their classification, which have an important bearing on the question of the efficiency of the nodules that may form when new species or strains of legumes are introduced in an area. It appears that characteristics other than their specificity when they happen to meet with the roots of Leguminosae are of little help in classification, but that there is some hope of a new science of bacterial genetics developing, which would lead to progress. G. B. MASEFIELD's paper shows that inoculation with selected *Rhizobium* strains may sometimes be beneficial with legumes of the ' cowpea cross-inoculation group ' in the tropics, as well as being generally necessary when plants such as clovers and French beans are introduced; a later report from Yangambi shows an 80 per cent increase in yield of groundnuts planted in a forest soil of low pH, as a result of inoculation.

NORRIS's paper gives further evidence that nitrogen fixation can take place satisfactorily with tropical types of legumes on acid soils, and that addition of lime is generally unnecessary, and MASEFIELD reviews the meagre information that has been published on the effects of environmental factors on nodulation in the tropics. I. H. RORISON, E. G. HALLSWORTH and co-workers, and L. DESSUREAUX describe investigations relating to the particular effects of manganese toxicity, aluminium toxicity, and calcium deficiency (which may all be associated with low soil pH values) on certain legumes. Work on the extraction of phosphate from insoluble sources by rhizosphere organisms, showing that acid-tolerant legumes have an advantage, is reported by R. J. SWABY and JOAN SHERBER. On the other hand, one of the chief points in J. M. VINCENT's paper on the survival of *Rhizobia* outside the nodule (which gives much practical information relevant to the use of cultures for inoculation in the field) is that soil acidity and acidity due to superphosphate can both have important adverse effects.

The last paper in the book is by W. ELLISON, on ' The Role of Legumes in Farm Ecology '. Agronomists in the tropics may react with varying prejudices to his remarks on legumes in tropical agriculture—for example, they seem to the reviewer to underrate the prospects of alternating pasture and arable; but a lesson may be learned from the contrast pointed out between New Zealand, where farmers depend on clover for the nitrogen supply in pastures, and Holland, where circumstances make it more profitable to apply large amounts of nitrogenous fertilizer.

It should be noted that matters such as the application of foliar analysis to the determination of fertilizer need in the groundnut or soybean crop were not dealt with at this meeting, nor did phosphorus, sulphur, potassium or magnesium receive much attention.—H.V.

HORTICULTURE IN THE BRITISH COMMONWEALTH: AN OUTLINE, 1958

D. Akenhead. *Technical Communication No. 26.* Commonwealth Bureau of Horticulture and Plantation Crops: Commonwealth Agricultural Bureaux, Farnham Royal, Bucks. 1959. *viii*+63 *pp.* 10*s*

The title of this publication is somewhat misleading as the compiler has not set out with the intention of giving an outline of the status and practice of horticulture in the Commonwealth but, as indicated in the introduction, has aimed at listing the work in progress at research or experimental centres in Commonwealth countries on both horticultural crops and on some other crops such as sugar cane, cotton, tobacco and pyrethrum. This is an admirable intention and the publication will be a considerable aid to horticulturists, and some agriculturists, who wish to ascertain what work is being done on crops which interest them and where it is being done, so that they can obtain further information by communicating with the stations concerned. Reports of the work in progress are given under the headings of individual countries, which are listed alphabetically, the report for each territory covering all the relevant crops grown therein, but the reader seeking information on a particular crop can readily ascertain which territories, and which research stations, are working on it by reference to the index.

The compilation is based mainly on information given for the purpose by the Official Correspondents of the Bureau in different countries and variation in the approach of these correspondents is probably the main cause of the unevenness of the information given, which constitutes a flaw in certain sections of the publication. It is, for example, of little interest to horticultural workers of any kind to learn that buildings for Agricultural Departmental Headquarters have been under construction since 1949 in the Western District of British Honduras, whereas, on the other hand, those interested in rubber will be disappointed to find that the very large programme of work at the Rubber Research Institute of Malaya is discussed in three and a half lines which mention only the submission of a report by an advisory committee. There are also a certain number of inaccuracies, but these are relatively minor and of little importance since they are unlikely to mislead the specialists who will be the main users of the publication.

Without doubt the hope expressed by the compiler that ' despite certain inadequacies and blemishes ' the booklet will be ' found to possess a modicum of usefulness ' will be more than fulfilled and it is very much to be hoped that a further issue will be made in three or five years time to keep matters up to date.—C.C.W.

HANDBOOK OF CITRUS DISEASES IN FLORIDA

L. C. Knorr, R. F. Suit and E. P. DuCharme. University of Florida Agricultural Experiment Stations (*Bulletin No. 587*): Gainesville, 1957. 157 *pp.* (illus.)

There are relatively few modern handbooks dealing with the pathology of a single tropical or subtropical crop in such a competent and comprehensive manner as this publication and, although the book is primarily

directed to the grower of citrus, it is to be warmly recommended to anyone interested in citrus diseases and their control. However, its scope would have been widened considerably if a good bibliography had been included.

It is well written and printed, and clearly illustrated with black and white photographs. It has a good index, and a useful table in the list of contents indicating the parts of the plant that are attacked by the various diseases. The coloured plates on the front and back covers are a useful addition, but they are not well reproduced, and would have been less vulnerable if inserted in the centre of the book. The covers of paper-backed books are not the best place for illustrations.—R.F.B.

PRINCIPLES OF SUGAR TECHNOLOGY
Volume II. Crystallization

Edited by P. Honig. Elsevier Publishing Co.: Amsterdam, London, New York, Princeton, 1959. *xviii*+567 *pp.* (illus.). 95*s*

This book is the second to appear of the set of three volumes on the *Principles of Sugar Technology*. It contains contributions by H. E. C. Powers on crystallography; F. H. C. Kelly on solubility; A. van Hook on crystallization theory; P. Honig on conductivity control and general chemical aspects; T. R. Gillett on control methods and equipment; R. C. L. Bosworth on the application of heat transfer measurements; W. F. Alewijn on general technology; A. L. Webre on circulation; G. C. de Bruyn on crystallization of massecuites by cooling; J. H. Payne on conditioning of massecuites in crystallizers and K. Douwes Dekker on recovery from low-grade boilings.

An important criticism of the present volume is that as in the first of the series the editor has adopted far too loose-reined a policy; for example the definition of supersaturation is given no less than six times and again the solubility of sucrose is discussed in four different articles. This is typical of the volume as a whole so that anyone wishing to read up a particular aspect must be prepared for a considerable search. But more important is the fact that the book, being a collection of articles, lacks any sort of significant form; a more severe editor could have pruned the volume to half its present length and cost and so presented the subject of sugar crystallization in an altogether more coherent fashion. It is only fair to state, however, that technologists will find much to enjoy in these pages and, as the articles contain material which is often not easily available elsewhere, all sugar technology libraries will acquire at least one copy of this work. Individual technologists, however, unless they happen to be particularly interested in the field of crystallization, will probably decide against spending 95*s* for this book.—W.S.W.

VEGETATION MAP OF AFRICA SOUTH OF THE TROPIC OF CANCER

Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale with the assistance of U.N.E.S.C.O. Explanatory notes by R. W. J. Keay. Oxford University Press: London, 1959. 24 *pp.* 15*s*

I attended the Second Plenary Meeting of l'Association pour l'Etude Taxonomique de la Flore d'Afrique Tropicale held in Oxford in the autumn

of 1953 when the production of this map was first discussed. Members were asked to put forward their views and a preliminary map was prepared. This final version was entrusted to an editorial committee of experts from various countries and is a fine example of the international cooperation which A.E.T.F.A.T. has engendered. U.N.E.S.C.O. has assisted in the cost of publication.

The map is on the scale of 1:10 000 000 and an important feature is that it ' aims at showing the vegetation as it is today, and not the presumed climax types '. Thirty-five physiognomic vegetation types are clearly mapped and these are briefly and lucidly described in Mr KEAY's ' Explanatory Notes ', which have a French translation by M. AUBRÉVILLE. Although the map may be on too small a scale to be of real use to those people working within an individual territory, it is urgently needed in the present state of African development, and will be of the greatest value to teachers, students, agriculturists, planners, and all who need an up-to-date assessment of the vegetation of Africa south of the Tropic of Cancer.

The retention of the terms ' savanna ' and ' steppe ' is, I think, unfortunate, and I feel that Mr KEAY would agree with this, as he points out that both terms may be used, ' with suitable clarifying epithets, for physiognomic types ranging from purely herbaceous vegetation to open woodland '. The third edition of the *Shorter Oxford English Dictionary* (1952) defines savannah (their spelling) and steppe in almost identical words as a treeless plain. In Trinidad the College savanna corresponds to the American campus, while BEARD (1946) in his *Natural Vegetation of Trinidad* defines it ecologically as ' a short-grass community with or without scattered shrubs '. The natural savannas of Trinidad with their very acid, impoverished soil, often waterlogged, e.g. the Aripo savanna, correspond to the *padangs* of Malaysia (*padang* can also mean an open space such as a cricket ground) and are very different from the so-called savanna country of Africa. In this map the term ' savanna ' is used for vegetation in which perennial mesophytic grasses (e.g. *Hyparrhenia*) at least 80 cm high, with flat, basal and cauline leaves play an important part; such vegetation is usually burnt annually . . . The term ' steppe ' is used for vegetation in which annual plants are often abundant between the widely spaced perennial herbs; perennial grasses when present, have narrow, rolled or folded, mainly basal leaves, and are usually less than 80 cm high . . . It is far less liable to burning than is savanna.

The notes include an extensive and valuable bibliography of all the important ecological papers on African vegetation south of the Tropic of Cancer.

It would be an interesting and instructive exercise to superimpose upon the map, not only the more obvious climatic data and major soil types, but also the distribution of the main food and economic crops and the human and livestock populations. I have often wondered why the northern and southeastern areas of woodland in which *Isoberlinia* and *Brachystegia* are abundant are among the least populated and ulitized areas of Africa outside the deserts. I realize that the soils of these woodlands may be very poor and that tsetse are often present, but I feel that other factors must be involved, particularly as they enjoy a higher rainfall than some of the more densely populated adjoining regions.

I would like to congratulate A.E.T.F.A.T. and Mr KEAY on this timely and excellent production.—J.W.P.

TYPES AND BREEDS OF AFRICAN CATTLE

N. R. JOSHI, E. A. MCLAUGHLIN and R. W. PHILLIPS. *F.A.O. Agricultural Studies No. 37*: F.A.O.: Rome, 1957. *vi*+297 *pp.* (illus.). 15*s*

This monograph follows rapidly upon the publication of ' The indigenous cattle of the British dependent territories in Africa ' compiled by FAULKNER and EPSTEIN. It is therefore inevitable that the reviewer should take the latter publication as a basis for comparison of this new work produced under the auspices of the F.A.O.

The major criticism of the publication under review is that an empirical method of classification of the African cattle has been employed. This unorthodox classification neither follows the logical sequence of the various cattle migrations from Asia into the African continent, nor is it compiled on a regional basis. The result is that certain cattle breeds and types are difficult to place within the general framework used, and are even more difficult to find when searching through the pages of the book. Thus the Nganda cattle of Uganda, which are found in greatest concentration on the northern shores of Lake Victoria, are placed by the authors in group 5 of their classification, amongst the cattle of Central and Southern Africa defined by the authors as occurring ' from the flood plain of the Nile in the Sudan, through southwestern Uganda and Ruanda–Urundi to the Rhodesias, Bechuanaland, Swaziland and Basutoland '. It would have been preferable to have placed these crossbred cattle under group 6, ' the cattle types of East Africa '.

The unorthodox classification is so poorly defined that the characteristics of each group given in the text are at times contradicted by the photographs of each group presented on pages 8 to 19. Thus group 5 cattle are said to be characterized by ' small or vestigial humps ' whereupon we are shown a fine picture (Figure 6e) of a Nilotic bull bearing a remarkably pronounced well-formed cervico-thoracic hump. Indeed, it is only the first three illustrations of the eight shown in Figure 6 which show anything like ' small or vestigial humps '.

The authors of an omnibus publication of this nature are at the mercy of their overseas correspondents and some of the Government officials who are listed as having contributed to the data presented have given the authors poor service. For instance, a concise review of MCINTOSH's most excellent publication *Some Notes on the Abahima and the Cattle Industry of Ankole* (1938), would have been of greater value than the controversial notes on ' Management practices ' of Ankole cattle which appear on pages 150 to 151. MCINTOSH's paper, which incidentally is not listed in the bibliography, belies completely the sentence that ' milk and meat are utilized only to a limited extent by the Abahima '. Milk is not only fundamental to the social customs of the Abahima (e.g. those connected with birth, marriage and death) but also plays an important part in the diet of this important cattle-owning tribe.

Again on page 220 the authors state that the region occupied by the Bukedi cattle (which incidentally are more accurately spoken of as Nkedi

cattle) is situated on or near the equator. In point of fact no land in south-eastern Uganda is on or near the equator, with the exception of certain islands, and the main centre of this group of cattle is between two and four degrees north, in the districts comprising the Eastern and Northern Provinces of Uganda. The Bukedi cattle maintained at Entebbe Veterinary Station were transported artificially to that Station for purposes of study, and hence the climatological data presented in Table 105 (which refer to Entebbe) are of no relevance whatsoever to the area of Africa occupied by the breed in question.

The publication is amply supplied with photographs, unfortunately not all of them of a sufficiently high standard to enable the reader to appreciate the characteristics discussed in the accompanying text. In addition, the printers have so cut the edges of the photographic plates that in certain instances the identifying letters have been trimmed out of existence. This is seen in figures 5 and 7 where the reader must identify the various plates by a process of elimination!

In spite of the above criticisms, this pioneer work has fulfilled a most useful function in bridging the gap between the overall picture of African livestock, and that part of the picture which has already been adequately described by FAULKNER and EPSTEIN. However, it is to be regretted that these two publications could not have been compiled with a similar format, with a common system of classification, and it is to be hoped that future F.A.O. publications of this nature will place more emphasis on the system of classification employed and less emphasis on minor controversial details submitted by diverse overseas correspondents.—P.N.W.

ALIMENTACION DEL GANADO EN LA AMERICA LATINA

JORGE DE ALBA. La Prensa Medica Mexicana: Mexico, 1958. *xv*+337 *pp.* (illus.). *U.S.* $5.00

In this book on animal nutrition in Central America, Dr DE ALBA has amassed data which will be of great value in other parts of the tropics. The book deals with the feeding of all classes of farm stock with emphasis placed on the use of herbage. Other chapters deal with digestibility, balanced rations and deficiencies of both minerals and vitamins.

One of the most useful parts, both to the stockman and to the research worker, is the up-to-date appendix tables of chemical composition and digestibility. It is unfortunate, however, that the author, although giving a comprehensive bibliography, has not mentioned on which class of stock the determinations of digestibility of each feed have been made.

The book is well illustrated and clearly printed and could well form part of the library of any one who works with animals under tropical conditions. —M.H.B.

THE CONSERVATION OF NATURAL RESOURCES

R. C. HAW. Faber & Faber Ltd: London, 1959. 256 *pp.* (illus.) 30*s*

The material of this book falls into two parts. In the opening chapters, and again in the final one, the author outlines against a Southern Rhodesian background the wastage of natural resources of which man has been guilty.

The semi-popular style, which appears to be directed to European farmers in southern Africa, may irritate some professional soil conservationists but there is no doubt of the author's sincerity or that public opinion still needs to be stirred in these matters.

The bulk of the text is devoted to technical methods of soil and water conservation. The amount of detail given would be insufficient for the use of the book in training specialist staff; for example, only two kinds of levelling instrument are described out of the many which can be used. There is far too little advice which is applicable to small peasant farms as opposed to large European ones; while the book can hardly fulfil the author's and publishers' hope that it will be widely useful in other continents, where the priorities and methods of work would often differ from those given here.

A much more sketchy treatment is also given to irrigation, fish-farming and other resource uses such as farm production of methane. Obviously these cannot all be adequately covered in one book; but compression has led to serious omissions, such as a proper consideration of drainage in connection with irrigation.

Nevertheless all that is contained in the book is sound and useful for its own clientèle and its own region. If it succeeds in persuading farmers to undertake some of the measures proposed, it can be judged a worthy contribution to a great cause.—G.B.M.

THE STATE OF FOOD AND ARGICULTURE 1958

United Nations Food and Agriculture Organization: Rome; Her Majesty's Stationery Office: London, 1958 $x+222$ *pp.* (illus.) 12*s* 6*d*

This annual review of the state of world agriculture will be welcomed by tropical agriculturists as much for its special section on Africa South of the Sahara as for its general review of world agricultural statistics. These sections, together with others on the growth of forest industries, are a very worthy addition to F.A.O.'s annual review. There is obviously a limit to how many and how detailed statistics can be reviewed every year, and no purpose is served by republishing unimportant statistics annually. F.A.O. has the organization and facilities to review particular facets of world agriculture very thoroughly from time to time and these reviews provide a valuable and authoritative source of information on the topics covered to the workers in the field. We shall look forward to further periodic reviews of important argricultural regions and industries in future editions of this yearbook.—A.L.J.

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